MSc Program
Renewable Energy in Central and Eastern Europe

Energy aware spatial planning

Impact potential of settlement structures and opportunities for assessment tools to support sustainable municipal development

A Master Thesis submitted for the degree of
'Master of Science'

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25 November 2010, Wien

Affidavit

I, **URSULA M O L L A Y**, hereby declare

1. that I am the sole author of the present Master Thesis, " Energy aware spatial planning, Impact potential of settlement structures and opportunities for assessment tools to support sustainable municipal development ", 150 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Abstract

The master thesis analyses interrelationships of different scales and measures of spatial planning and energy issues in detail in order to highlight important interdependencies as well as to come to conclusions referring to synergies between specific spatial characteristics and trade-offs in terms of effects on the energy demand of the built environment. In addition the study comprises an analysis of selected tools for the assessment of energy efficiency of settlements, which allows for an evaluation of the tools concerning relevance, opportunities and shortcomings of the tools for awareness raising and as municipal decision support.

The detailed analysis of interrelationships and tools is finally set in context with questions of future sustainable municipal development and the potential role of spatial planning in terms of energy efficiency of municipalities.

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List of Abbreviations

BREEAM Communities	BRE Environmental Assessment Method for Communities
CHP	Combined heat and power
DH	District heating
EEA	European Energy Agency
EFES	Energieeffiziente Siedlungen (energy-efficient settlements)
EPBD	Energy Performance of Buildings Directive
FSI	Floor space index (floor area/living space per ground area)
GHG	Greenhouse gases
GOSOL	Solar- energetic simulation program for settlements
LBR	Land to building ratio (built-up proportion of a lot)
LEED ND	Leadership in Environmental and Energy Design – Neighbourhood Development
NRW	Nordrheinwestfahlen
OSR	Open space ratio (green, open space per ground area)
PT	Public transport
REN	Renewable energy
StROG	Steiermärkisches Raumordnungsgesetz (Spatial planning law for the Austrian province of Styria)
UMZ	Urban morphological zone
VMT	Vehicle miles travelled

1 Introduction

1.1 Motivation

In 2007 the Intergovernal Panel on Climate Change (IPCC) published the latest reports on the actual situation of worldwide climate change. In this report the experts highlight that:

> *'Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica)' (IPCC, 2007).*

Moreover it is stated in this report, that a further increase of global GHG emissions over the next few decades is most likely in case of (only) continuing with today's policies for climate change mitigation policies and related development.
IPPC comes to the result that – facing the current developments – a temperature increase of between +1.8°C and + 4.0°C up to 2100 will have to be faced (compared to the average worldwide temperature of 1980-1999). It is very likely that life on earth will change to a certain extent. In case of approaching the higher range of these scenarios concerning global warming it is expected to face very serious impacts on sea levels and regional climate changes with negative effects on remaining possibilities for future human life on earth in total (due to effects on ecosystems and food production, availability of water, health, flooding and storms).
Thus currently at EU-level, it is the objective to agree post Kyoto policies with the objective of keeping global warming below 2°C (above the pre-industrial temperature). This aim necessitates of a massive reduction of GHG emissions also in Austria, which can only be achieved by a concerted action of all sectors producing emissions directly together with other fields with influence on the level of GHG-emissions, as i.e. spatial planning.

Spatial development and related energy use

Most of human life is spent in settlements, villages and cities. In this environment, energy is used for various purposes. The configuration of these structures and their organisation is an essential factor for future energy demand in terms of the needed amount of energy as well as in terms of renewable or non-renewable energy sources.

Spatial planning decisions have a major impact on the development of new settlements (in terms of location, densities, orientation of buildings, etc.) as well as on the transformation of already existing built structures. Due to its effect on energy demand for space heating and transport issues, the way in which these built up structures are configured and organised is one of the key questions for future energy demand.

In Austria, urban development (in terms of built structures) – as this is the case in many other European countries as well – is mainly driven or at least authorised by municipal decisions. Consequently, our common options for a future, more energy efficient development are highly dependent on those decisions[1].

The study at hand tries to support such a sustainable municipal development by providing an overview on relevant information and interdependencies between spatial planning and energy issues as well as by analysing the relevance and coverage of (existing) tools, which are focused on the assessment of energy and spatial development relations in order to support municipal decision-making.

1.2 Core objective and structure of work

The master thesis is aiming at enhancing sustainable municipal development in terms of energy efficiency and resource use in order to contribute to climate change mitigation. The core objective and focus of the study is the assessment of the influence spatial planning measures at a municipal level can have (if set in an energy aware way).

To provide information on this question, following issues shall be analysed in detail and set in context with municipal development:

- Which important interdependencies between spatial planning in terms of built environment and energy efficiency as well as in terms of the use of renewable energies have to be considered?
- How do different scales of spatial planning relate to these issues? How much influence can be stated by spatial planning measures?
- Where are options and barriers to be dealt with in context with these interdependencies?
- What are the trends and framework conditions to be considered?

1 As also identified in the Austrian Energy Strategy (March 2010), in which spatial planning is mentioned as an important strategic element and integrated as a horizontal issue in a broad range of activity fields.

- Which assessment tools exist, to assess the relation between spatial planning and energy issues?
- How do these tools evaluate the described interrelations? Do they cover the analysed issues?
- What are the major differences between the analysed tools?
- Are the tools relevant as municipal decision support and can municipal actors use them?

Due to the focus of the study at hand, building related measures (especially renovation) and issues of human behaviour are not analysed in detail, although stated to be important.

The work is structured along the main questions to be answered:

- Analysis of interdependencies between spatial planning for the built environment and related energy issues (chapter 2);
- Analysis of selected tools for assessment and certification (chapter 3);
- Synopsis and conclusions derived (chapter 4).

2 Interdependencies between spatial planning in the built environment and related energy issues

The chapter at hand presents the relationship between measures of spatial planning at different scales and energy issues as well as their importance according to a comprehensive literature review (studies and empirical analyses, usually referring to selected aspects). In a second step those interrelations are analysed in terms of relevant interdependencies, synergies and trade-offs concerning the effects of implementation of divers measures of spatial planning.

2.1 Scales of spatial planning and related aspects of energy demand

Spatial planning encompasses the structuring of ground space and its uses within a country. In Austria it is generally regulated in nine provincial laws (Austrian ‚Länder'[2]), where it is defined as systematic, forward-looking arrangement of an area, to provide for its sustainable use and the protection of respective habitat for purposes of common welfare. Spatial planning has to consider the existing situation and natural conditions including the protection of the environment as well as economic, social, sanitary and cultural needs of the population and it shall provide with the possibility for a free development of the individual within the community (Amt der Steiermärkischen Landesregierung (2010), StROG[3]). Hereby the regional laws are subsidiary to laws at national level regarding sectoral measures and planning activities with territorial reference (e.g. railways, the interregional road network, forest, etc.).

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2 Here, the Styrian law published in 2010 has been chosen as an example, the definition of spatial planning in other provinces is similar.

3 Original wording of StROG 2010: *'Raumordnung im Sinn dieses Gesetzes ist die planmäßige, vorausschauende Gestaltung eines Gebietes, um die nachhaltige und bestmögliche Nutzung und Sicherung des Lebensraumes im Interesse des Gemeinwohles zu gewährleisten. Dabei ist, ausgehend von den gegebenen Strukturverhältnissen, auf die natürlichen Gegebenheiten, auf die Erfordernisse des Umweltschutzes sowie die wirtschaftlichen, sozialen, gesundheitlichen und kulturellen Bedürfnisse der Bevölkerung und die freie Entfaltung der Persönlichkeit in der Gemeinschaft Bedacht zu nehmen.'* (Amt der Steiermärkischen Landesregierung (2010), StROG, §1, Abs.2)

Nevertheless, local implementation of those laws is the responsibility of the municipalities. Based on the provisions at national and the respective provincial level, the municipality lays down local development concepts, land use and local construction plans.

Implementation of spatial planning measures

Hence, in the urban sphere spatial planning is based on national and regional legal requirements and planning strategies, but decisions are taken at a very local level. In this context, spatial planning decisions mainly are taken at municipal level, generally referring to:

- Municipal land use plans
- Local construction plans, possibly including zoning bylaws

Municipal land use plans define the location of different functions and thus lay down the shape of the built up area and a specific functional mix in a municipality. Dependent on the regulation set by the respective spatial planning law, areas are dedicated to a specific use of land. Changes of land use plans usually comprise new zoning regulations and a stepwise extension of urban areas, but may contain changes in single cases (plot for plot) as well. Mainly in growing municipalities (in terms of population growth) also the planning of larger development areas (new quarters as part of a city) plays an important role in developing an entire urban settlement.

Referring to energy issues, important aspects of spatial planning in terms of locational decisions are to be defined as follows:

(1) Topography is especially important for zoning and the location of settlements in hilly areas;

(2) Municipal shape in total comprises e.g. the issues of compact cities/villages versus urban corridors/ribbon-built villages versus sprawled settlements);

(3) Land use-mix is laid down by defining functions within a municipality, e.g. housing and industry/services, discussion of mono-functional versus multi-functional areas/ areas of mixed use;

(4) Green spaces/ open spaces are also defined as an important function, i.e. location within the urban environment, size and share of green public (and private) spaces;

Local construction plans and zoning bylaws define density and design of settlements based on an already defined land use. Thus in those plans the following characteristics are laid down:

- Plot plan defining the allocation and demarcation of parcels for selling plots and/or construction of buildings;
- Urban infrastructure, especially the layout of streets and pathways, car parking spaces;
- Building types and height of buildings (i.e. apartment buildings, terraced houses and single family houses);
- Coverage type (i.e. closed coverage, semi-detached, detached housing);
- Building lines limiting the area of plots in terms of defining the area of allowed coverage (sealing of land) according to regulations (obligatory), including a specification for maximum built up land within a plot;
- Partly also regulations on design and landscape gardening (e.g. arrangement and design of fences, ...);

For large development areas (developed by one actor or a group of actors together) the definition of a master plan for building up an area may be another important step for influencing future options in terms of energy demand.

Important aspects of spatial planning decisions referring to density and design (in local construction plans) are to be defined as follows:

(5) Urban density: persons in place (inhabitants and working population)

(6) Solar orientation: important for passive and active use of solar energy, avoidance of shading

(7) Wind regime: consideration of the main wind direction and specific characteristics of the area

(8) Connectivity of streets and pathways: avoidance of detours, supporting short distances within the city (especially for walking and cycling)

Relevant aspects of energy demand affected by the field of spatial planning

The topic of the master thesis at hand refers mainly to land use plans and local construction plans as relevant scales of spatial planning. Due to such planning measures different effects on the issue of energy use can be derived.

As important aspects respectively objectives relating to energy demand (which can be influenced by spatial planning) are defined:

(a) Minimising losses of (heat) energy

(b) Maximising passive (heat) energy gains

(c) Active use of decentral renewable energy: solar energy (solar thermal appliances, photovoltaics) and other decentral renewables (e.g. wind, geothermal)

(d) Increase efficiency of energy services by common supply (e.g. central heat provision: district heat networks including use of waste-heat or public transport provision)

(e) Minimising (fossil) vehicle miles travelled by supporting environmentally friendly (not fossil energy dependent) mobility, ‘slow’ modes of transport (walking, cycling)

Energy demand in spheres of living affected by spatial planning

Thus spatial planning decisions affect the energy demand mainly in two spheres of human living: the built environment (mainly heat demand) and the (fossil) energy demand for mobility[4]. A general difficulty of energy aware planning is the difference between effects on the built environment and effects on mobility modes.

Effects on the built environment can be calculated and simulated widely due to consideration of technical parameters (e.g. thermal characteristics of buildings envelopes, distances between buildings and related heat densities and losses, etc.). Additionally a number of legal requirements can be set and is increasingly being set in the context of buildings and energy demand (e.g. thermal standards for buildings, duty for solar thermal use for new buildings, ‘nearly-zero-energy buildings’ according to EPBD 2010[5] etc.)

Mobility (including modal choice, trip length and trip frequency) in contrast is not only influenced by settlement structures, good options for walking and cycling or for the supply with public transport. In terms of mobility there are a number of additional factors influencing the decision of each person (e.g. car ownership, income, mobility prices, attitudes). Thus referring to mobility, spatial planning has to be seen as an instrument of providing good options for public transport as well as for walking and cycling – without ‘guarantee’ of success.

As shown in the following figure, those two spheres of living comprise a considerable share of the total final energy consumption in Austria (in 2008). In total about 63% of the 1,088,538 TJ final energy in Austria was consumed by the sectors ‘traction’ (376,420 TJ) and ‘space heating and air conditioning’ (314,286 TJ) (Statistik Austria 2010, see sectors below).

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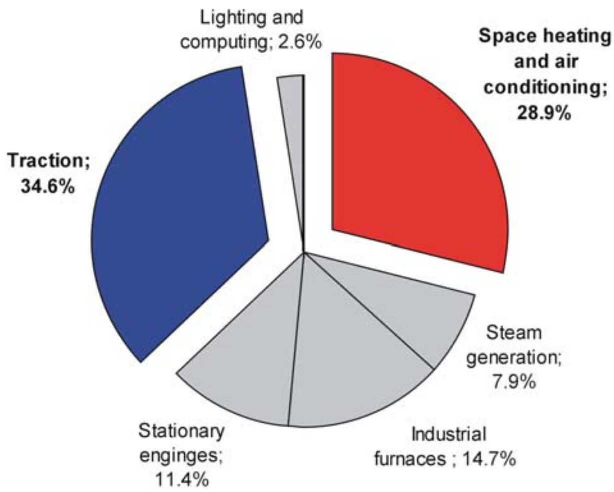
4 Although electric mobility is a kind of mobility which could be affected by those decisions as well, it is not stated to have a primary interdependency with spatial planning decisions beyond those of fossil driven cars. Thus effects on electric mobility are not considered individually.

5 EPBD 2010 (recast), Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

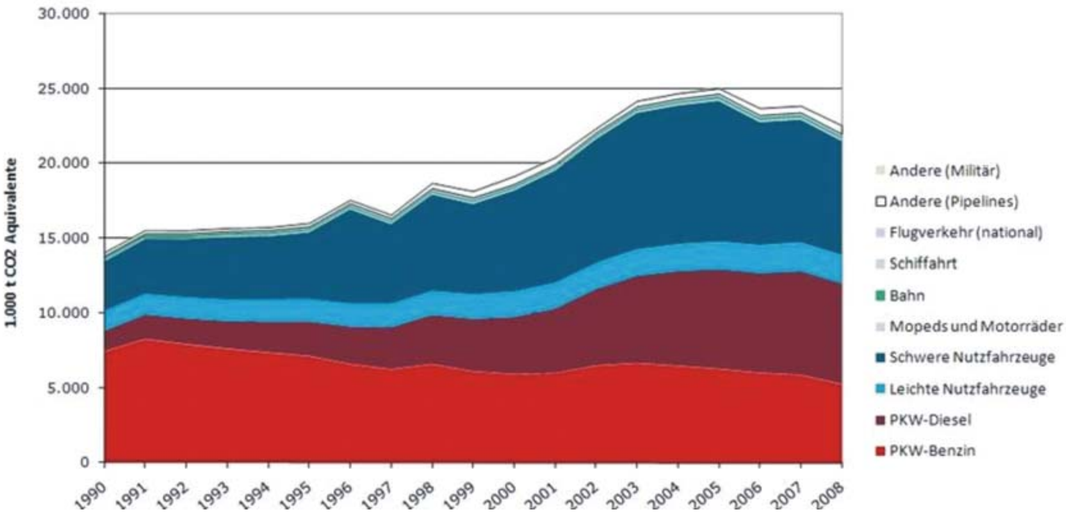
Figure 1: Final energy consumption by sectors in Austria 2008



Source: Statistik Austria 2010 (data)

It has to be mentioned, that this energy demand is including not only the energy demand of households (in a wider sense). Thus, energy aware spatial planning in terms of urban development can influence a large share, but not the total amount of energy used in those sectors. Especially the sector of 'traction' is including road and off-road traffic as well as private and commercial transport. It therefore contains not only car traffic but also additional uses as e.g. commercial transport by camions as an important share of (fossil) energy demand in this sector. Nevertheless, as presented in the following figure, the energy use of car traffic holds a high share of GHG-emissions.

Figure 2: GH Gemissions of the transport sector in Austria 1990-2008 (including export of fuels)



Source: Umweltbundesamt Österreich 2010 (without international air transport and mobile engines (agricultural tractors, construction vehicles)

The significant share of GHG-emissions (CO_2-equivalents) in the transport sector of Austria, which is caused by cars, is clearly shown (see figure: dark and light red area). About half of the total GHG-emissions are caused by cars, this amount steadily increased in the last decades. Despite considerable improvements referring to emissions from motorised vehicles, due to the increase of the number of vehicles and VMT, technical innovation could only reduce additional emissions. Only between 2007 and 2008 a total reduction of GHG emissions from car transport is indicated from statistics (Umweltbundesamt Österreich 2010).

Description of relevant aspects of energy demand and its relation to spatial planning

According to the scales of spatial planning and the objectives concerning energy demand, characteristics and interdependencies from literature are described in the following chapters (2.2 and 2.3).

All subchapters on aspects of spatial planning decisions (2.2.1 – 2.3.4) present a table for a first overview on possible effects with relevance for energy demand (as shown below as an example).

Minimising losses of (heat) energy	*Maximising passive (heat) energy gains*	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

This overview in each of the subchapters points out:

- Important effects on objectives concerning energy demand highlighted in yellow (e.g. ‘minimising losses of (heat) energy’);
- Effects of relevance but not as important or less analysed respectively described only qualitatively are highlighted in light yellow and written in italic letters (e.g. ‘maximising passive (heat) energy gains’),
- whereas effects without importance (in this context) are not highlighted and written in grey letters (e.g. other cells).

Following this overview on relevant effects of a specific spatial planning topic, these stated effects are described in more detail (based on available literature). At the end of each chapter rough guidelines on most important aspects are presented, structured by energy issues and highlighting the aspects, which should be taken into consideration in context with this specific topic of spatial planning.

An overview on all aspects of planning decisions and their potential effects is shown in chapter 2.4.

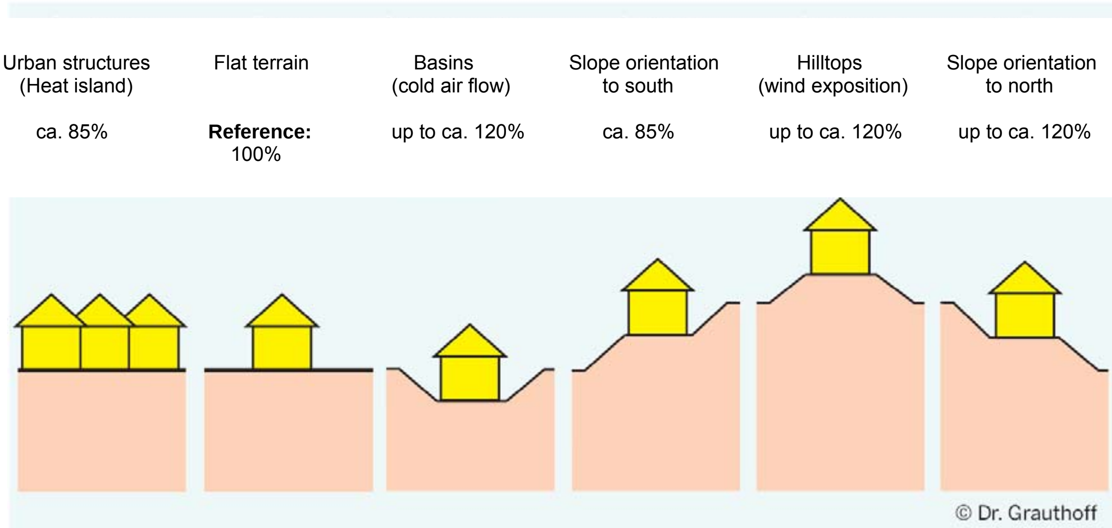
2.2 Land use plans – location of urban functions and functional mix

2.2.1 Consideration of Topography

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	*Minimising VMT, environmentally friendly mobility*

The topography of an area has to be seen as an important characteristic in the urban planning context, which may influence both, the shape of a municipality (referring to available settlement area) as well as energy losses and energy gains due to exposition of buildings to the sun and to wind.
The local conditions of topography have to be taken into account as given, but due to certain conditions considerable effects on heat demand (losses and gains) in relation to the local climate have to be stated concerning the location of a building.

Figure 3: Energy demand for space heating in context with local climate conditions



Source: EnergieAgentur.NRW 2008 (Copyright Dr. Grauthoff), own translation

In relation to microclimate respectively local wind regimes different situations can be shown as ideal types of such relations. Whereas studies on this relations show similar trends, the quantitative results in terms of heat losses respectively heat savings differ widely. The results shown by EnergieAgentur.NRW (2008) i.e. are pointing out relatively low heat losses/savings:

- Urban heat islands: reduce the heat demand (up to -15%)
- Basins: cold air flowing basins increase heat demand (up to +20%)

- Hilltops: exposition to wind increases heat demand (up to +10%[6])

In contrast to those results, Wende et.al. (2009) refers to results on heat loss due to the effect of wind with by far higher effects:

- Hilltops: exposition to wind increases heat demand (up to +100%)
- Wind shading by topography: prevention of wind may reduce heat demand (up to -50%).

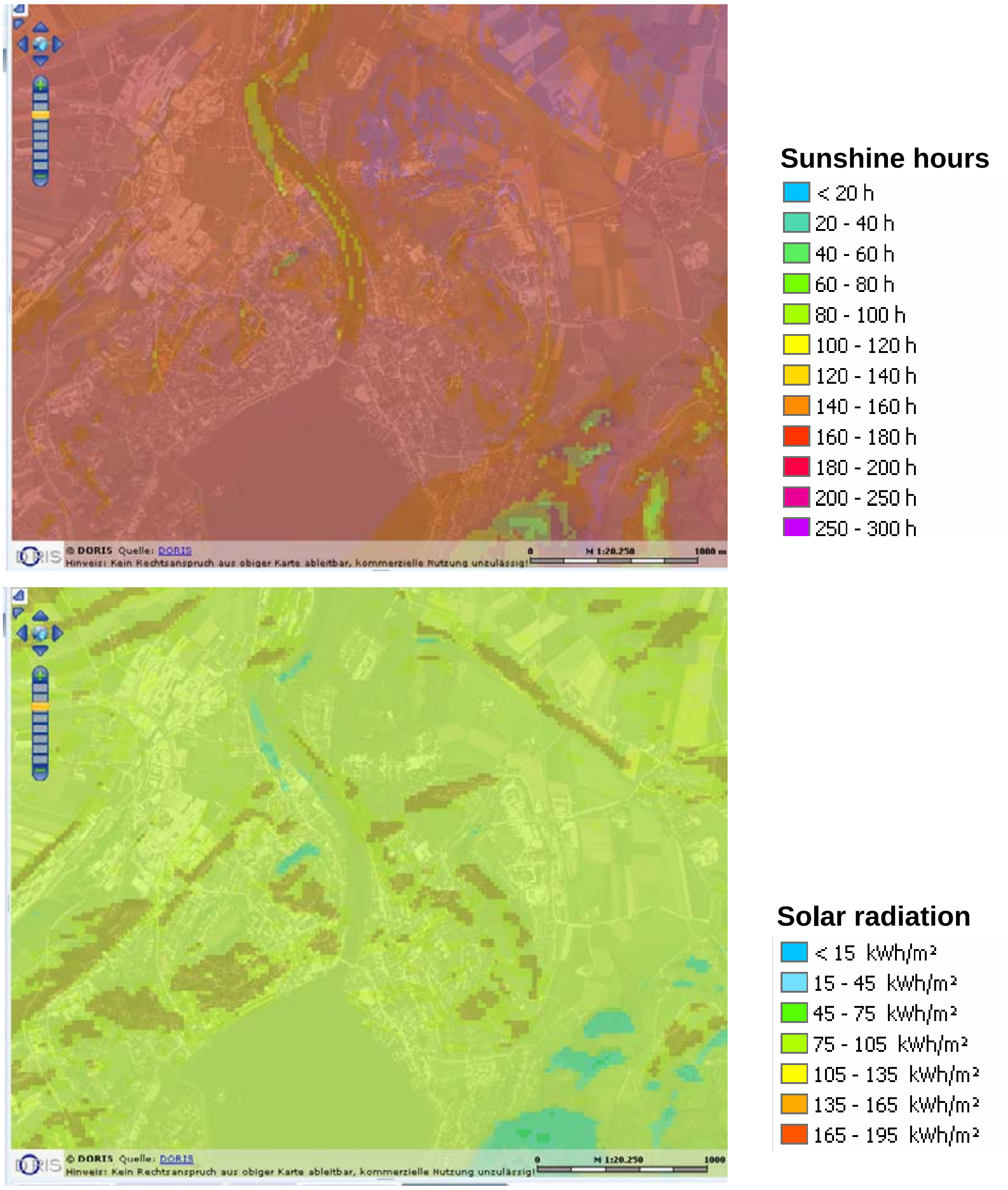
Additionally the orientation of the slope a building is located on is of major importance for gaining passive solar energy and conclusively of its heat demand (ranging between slope orientation to south, up to -15%, and slope orientation to north, up to +15%) (EnergieAgentur.NRW 2008) but also for the options of active solar use (see also chapter 2.3.2, orientation of buildings, shading by buildings). Moreover, shading due to topography should be avoided already in the phase of land use planning.

Solar maps may be used as a general support for spatial planners and planning actors in land use planning, especially in mountainous or hilly regions, whereas for building related solar energy issues the specific conditions at a location have to be analysed in detail. In such solar maps (see below solar maps for the city of Gmunden as an example) most important factors with effects on active and passive solar use - sunshine hours and solar radiation – are depicted to support energy aware land use decisions.

Areas of very low available solar energy should only be utilised as building land (if at all) if it is argued due to other important factors. In principle such areas should stay free of any construction (e.g. green space).

[6] This should not be true for Passive Houses due to their highly air tight construction.

Figure 4: Upper Austria, sunshine hours and solar radiation in Gmunden (example)



Source: Doris-Atlas, Upper Austria

Finally topography might have an impact on environmental friendly modes of mobility, as steep slopes lower the comfort respectively increase the need of physical strength of walking and cycling. Those circumstances are less analysed, but should be taken into account as well.

General guiding principles referring to consideration of topography

Following main principles can be formulated based on available literature:

- ***Minimising losses of (heat) energy***
    - Consideration of wind regimes (main wind direction, in detail, a wind analysis is able to show the situation at a certain location),
    - Attention on hilltops and basins (wind regime),
    - Advantages by wind shading possible (wind regime, shading by buildings or by topography)
    - Avoidance of north slopes (solar heat losses)
- ***Maximising passive (heat) energy gains***
    - Avoidance of sun shading by topography - options for solar use (in detail, a solar analysis is necessary to balance optimal solar use within urban structures)
- ***Active use of decentral renewable energy***
    - Active solar use (see above)
- ***Minimising VMT, environmentally friendly mobility***
    - Avoidance of steep slopes (to enhance comfortable walking and cycling)

2.2.2 Municipal Shape and Location of Functions

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

Spatial planning decisions have to be based on the existing situation, especially concerning the settlement structures and shapes of municipalities.

On the one hand these circumstances have to be considered as a background of planning. The shape of municipalities has developed in the past, mainly in the course of population growth. Population change, on the other hand, is a chance to change shapes and settlement structures again in the course of the coming decades. Starting as relatively compact settlements built and used with the background of mainly slow mobility options, especially with the growing importance of the private car and increasing car ownership, urban sprawl started and shapes of cities and villages changed during the past decades.

Despite this general development trend of increasing car dependency in the younger past, especially villages and small cities show different traditional settlement patterns as a starting point. Those settlement patterns mainly developed due to topography and the needs of agricultural production. As an example - in rural areas of North-Eastern Austria rather compact ribbon-built villages prevail, whereas mountainous Western Austria traditionally shows more dispersed settlements with a number of small villages and settlements.

Effects of decisions on location and municipal shape

The location of functions has to be put in the context of existing structures. It is having considerable impact on the energy needs for transport due to distances (e.g. to the centre, to the work place, to leisure facilities, etc.) and due to the options for the use of public transport and/or other environmentally friendly modes of mobility. Especially in terms of housing it seems clear, that this aspect is strongly linked to the question of densities. A medium to high density urban development of a certain size (in terms of number of population) might have a chance to become a new local centre with local supply and with access to high level public transport, even if it is not connected to the existing built up land (decentralised concentration, see below). In contrast to this situation, it is unlikely to have a comfortable connection to public transport in a dispersed settlement area outside of the (more densely) built up urban land (urban sprawl), such areas usually stay dependent on motorised car transport.

Referring to commuting, Litman (2010) presents centeredness[7] as an important factor for the use of public transport. He points out a share of typically 30-60% of commuters using public transport from centred locations against only 5-15% from dispersed locations.

A recent study from Ewing and Cervero (2010) also comes to the conclusion that the location of functions is of high importance for reducing VMT and enhancing public transport use. Referring to the distance to downtown average elasticity can be derived for VMT of about -0.22, which is by far the highest effect on VMT according to the meta study.

Another decisive issue in terms of energy demand (for transport) and location of functions is referring to the location of shopping facilities. Shopping centres at the edge of cities are car based (large parking sites and location at a high level road infrastructure, but usually no or far less attractive public transport accessibility). Hence, they and lessen options for walking and cycling due to longer distances. From an overall view on urban structures and functions they often lead to a loss of

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7 Centeredness defined as portion of commercial, employment and other activities in major activity centers (Litman 2010, p.46)

functions in the city centres, which is a difficult situation in terms staying an attractive, lively multifunctional city or village centre.

The municipal shape as an indicator of energy demand for mobility is less discussed in literature, even if it is directly linked to the question of location of functions. Nonetheless, there are circumstances and interrelationships to be considered, namely:

- Besides consideration of different densities, it seems clear, that distances within a compact, concentric built urban settlement are shorter than within a compact ribbon-built village (on the basis of calculation).
- Fixed settlement boundaries support more compact municipalities respectively hinder urban sprawl (with the consequence of considerably lower average densities, further discussed in chapter 2.3.1)
- On the other hand, corridors of green space allow the connection of the built environment with nature (with positive effects on air quality, heat islands and life quality in general). This aspect is especially important for larger cities and agglomerations.

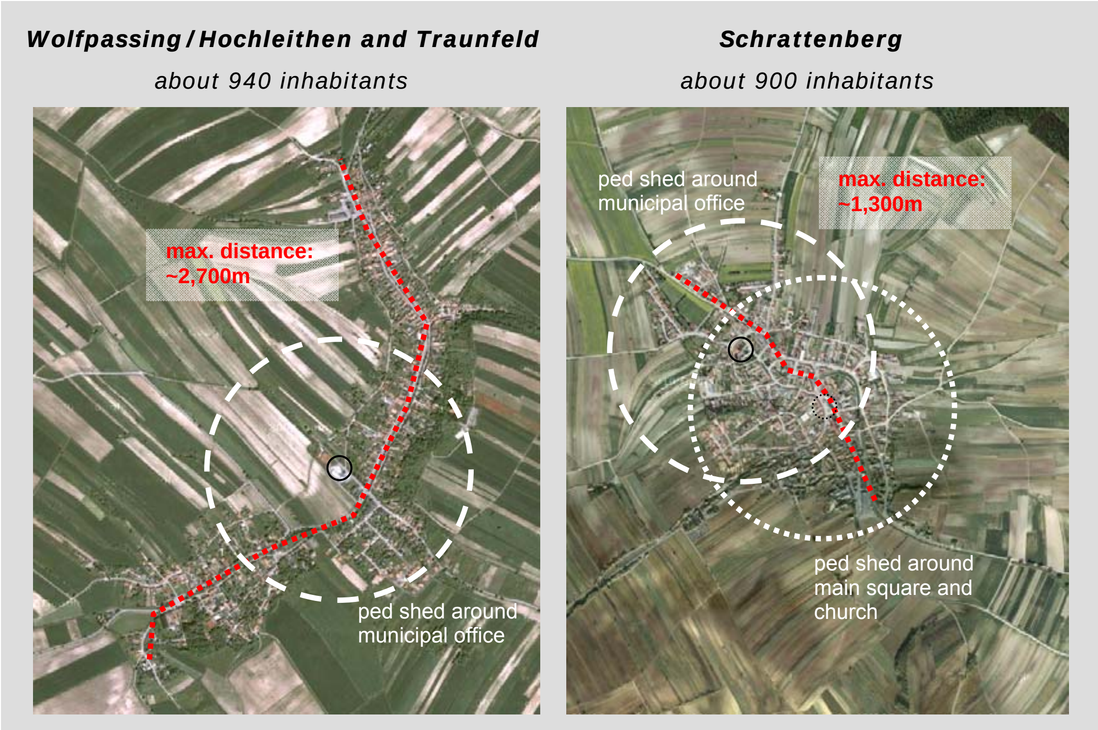
The following figure presents an example of two differing types of municipal shape affecting distances within a village. The two settlement areas in Lower Austria are of about the same size (about 900 inhabitants); the scale of the maps is the same.

The villages of Wolfpassing and Traunfeld[8] exemplarily show a linear settlement with a spread of about 2.7 km between the most distant locations. Less than half of the population is located within a ped shed of about 500m radius around the municipal office.

Schrattenberg, in contrast, is presenting an example for a rather concentric built settlement. The maximum distance between two locations within the settlement is only about 1.3 km (less than half of Wolfpassing/Traunfeld). Even though the municipal office is not located in the centre of the village, more than 4/5 of the inhabitants live within a ped shed of 500 m around the office. Taking the main square of Schrattenberg as the centre, nearly the total population is living within its catchment area.

[8] Due to the fact, that the two villages (Wolfpassing and Traunfeld, being a part of the municipality of Hochleithen both) have nearly merged in the past, they are seen as one linear settlement. They have also only one common municipal office.

Figure 5: Shapes of villages in Lower Austria with similar number of inhabitants but different shapes

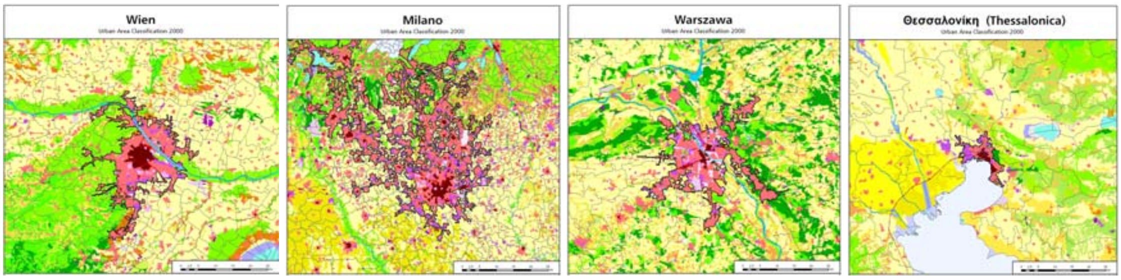


Source: Google Maps, own composition

In case of growing population, municipalities should strive for an extension within the ped shed. For the exemplary municipality of Wolfpassing/Traunfeld this can only help to avoid further linear spread but it will not lead to a notedly more compact shape for ages. The example of Schrattenberg would be able to hold a (though not dense, but) compact structure with favourable distance for walking and cycling within the built up area.

Referring to large cities and metropolises, the question of overall shape and its relation to energy demand is even more difficult to be answered. As an example for large cities, the following maps show the shape of built up land in different European cities (considering the morphological area of built up land beyond the administrative border) as produced in the course of a European research project (FP7) (Schremmer et.al. 2009, Schremmer et.al. 2010). The shapes of these selected European cities clearly show different prerequisites especially (but not exclusively) for transport issues (e.g. public transport).

Figure 6: Shapes of large cities – the Urban Morphological Zone (UMZ) of Vienna, Milano, Warsaw and Thessalonica



Note: The urban morphological zone, derived from CORINE land cover data, comprises contiguously built up urban area. Light red colour indicates discontinuous urban fabric; dark red colour indicates continuous urban fabric.

Source: OIR 2009, European Energy Agency (data)

Wegener/Fürst (1999) present results of empirical studies on the interrelation of land use and transport. In terms of location and municipal characteristics they find that:

- The distance to main employment centres determines the trip length of travelled distances
- The distance to public transport stops strongly influences the modal choice for public transport.

The interrelation of municipal shape and energy demand is analysed mainly in relation to the discussion on decentralised concentration referring to mobility options. Positive effects are expected due to urban development along corridors with higher densities and with major focal points of infrastructure supply (high level public transport provision and social infrastructure including local supply of goods and shopping)[9] supporting public transport modes. Those structures can also support walking and cycling as combined modes together with high-level public transport within the range of the public transport stop.

General guiding principles referring to municipal shape and location of functions

Following main principles can be formulated based on available literature:

- ***Efficiency due to energy services by common supply***
    - o Support development and densification in the vicinity of high level public transport (decentralised centralisation)
- ***Minimising VMT, environmentally friendly mobility***
    - o Location in short distances to the centre(s) if possible

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9 In the USA this topic is discussed mainly under the notion of Transit Oriented Development (TOD)

- o Avoidance of dispersed settlements outside the boundaries of an existing built up area
- o Striving for a compact (rather concentric formed) shape of a municipality (especially for small cities and villages)

2.2.3 Functional Mix of Land Use

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

One of the most important tasks of spatial planning is the decision on the location of different functional uses of space. Land use plans lay down residential and industrial areas as well as areas of mixed use and green space in between the built up land[10].
In terms of built environment related energy demand the support of efficiency due to energy services by common supply is possible by consideration of the location of immobile renewable energy sources (esp. waste heat). For the use of those energy sources the consideration of location and densities of residential and service areas in the vicinity of the useful heat source are necessary (district heat networks). Another possible synergy is the common use of residential heat demand and industry or services with a high heat demand to ensure sufficient average heat densities during the year (see also the discussion on district heating networks in relation to densities, chapter 2.3.1).
In terms of mobility related energy demand, the aspect of functional mix of settlements is of importance to minimise vehicle miles travelled by support of environmentally friendly mobility (public transport, walking and cycling).
Referring to functional mix, it has been shown by empirical analyses (e.g. Wegener/Fürst 1999, Cervero and Kockelman 1996, Handy 2005, California Energy Commission 2009, Litman 2010, Ewing and Cervero 2010) that mixed functional structures tend to:

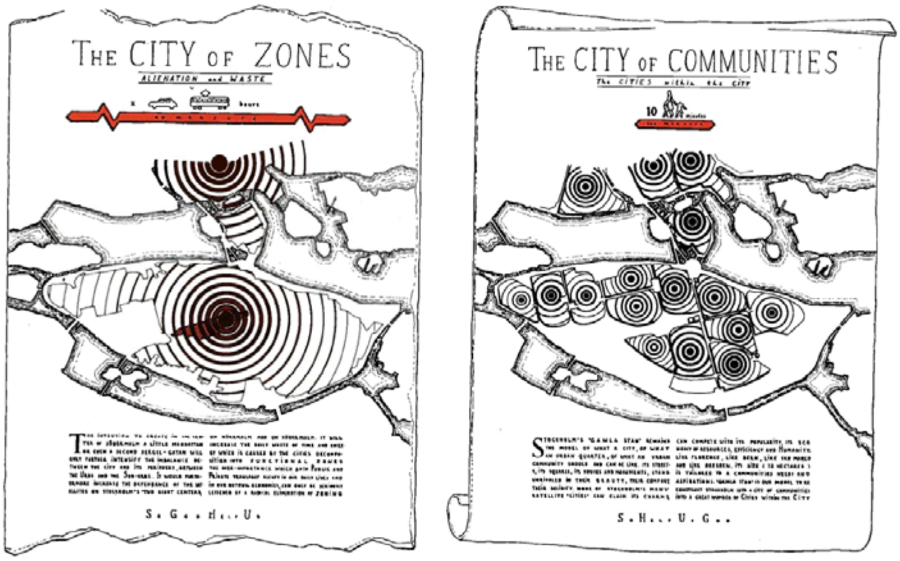
- Shorter distances travelled in general
- Better conditions for shopping in nearby centres with the possibility of walking and cycling
- Less peaks of transport demand and urban life (e.g. purely residential areas tend to show activities mainly in the morning and in the evening)

10 Options due to green space are discussed in the following chapter.

- A more balanced density of people (residents and working population, e.g. offices) during the day may lead to
  - Less difficulties to provide comfortable public transport with short intervals during the day which leads to a higher modal split of public traffic
  - Better options of local supply (small shops) due to higher demand for services

Thus in this context the concept of city of short distances and neighbourhood centres respectively mixed use neighbourhoods have to be mentioned. As put by the Congress for the new urbanism (figure below), the 'city of communities' consists of local centres providing options for walking and cycling. They are stated to be of importance for lessening car transport due to local supply within accessible pedestrian sheds.

Figure 7: City of communities – pedestrian sheds

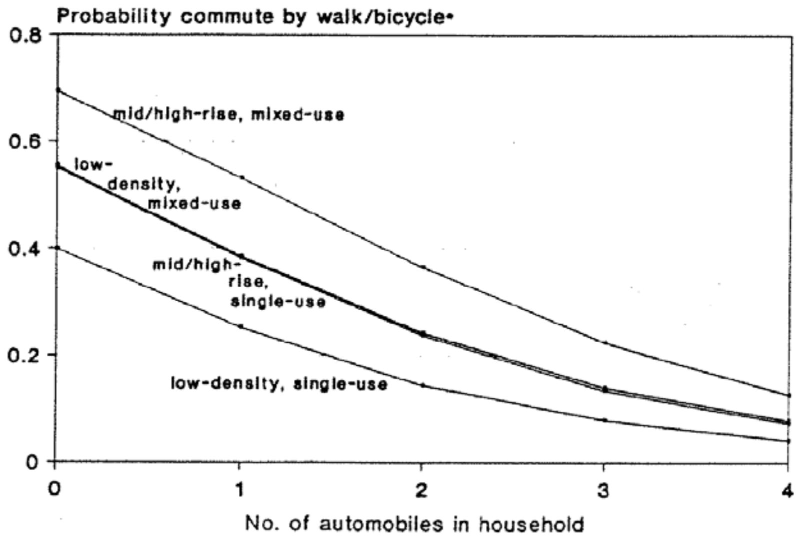


Source: Congress for the new urbanism, without date (original source: Leon Krier (Krier, Léon. Architecture: Choice or Fate. Andreas Papadakis, 1998)

A statistical analysis of about 45,000 households in the USA points out the correlation between the probabilities of walking or cycling and the type of settlements the persons live in (Ewing et.al. 2007). According to this data, for walking and cycling mixed use is even more important than density (for short distances).

Additionally the importance of car ownership has to be taken into account. Whereas the differences between different settlement types are considerable for households with only one car, both – differences and probability – are less clear for households with 2 cars and even less in households with 3 and 4 cars.

Figure 8: Effects of mixed use (and density) on walking and biking for commuting for 1 mile home to work distance



Source: Ewing et.al. 2007 (original source: Cervero 1996), based on data for more than 45,000 U.S. households

In a meta study of Handy (2005a), available literature has been evaluated in terms of empirical results on the relation between built environment and walking and cycling ('active travel'). Referring to the neighbourhood type it has been shown, that traditional neighbourhood types with local centres and supply of local infrastructure within ped-sheds show positive effects on all trips, especially for the way to shops and partly to work (table below).

Table 1: Findings on 'active travel' (walking and cycling) and neighbourhood type from literature

Category	Measure	To work	To shop	To school	All trips
Neighborhood type	Traditional neighborhood versus suburban neighborhood	+	++		+0
	Transit neighborhood versus automobile neighborhood	+			
	Traditional development versus planned-unit development	0			
	Urban neighborhood versus suburban neighborhood				+
	Walkable neighborhood versus suburban neighborhood				+
	LADUF rating: high, medium, low				+
	Traditional factor				0
	Suburban factor				0

Key: + positive relationship, – negative relationship, 0 no statistically significant relationship; larger symbols indicated Tier 1 studies

Source: Handy 2005a

In this study additionally a positive relationship between land use mix and 'active travel' has been shown in several results. Positive correlation was verified for the characteristics of:

- retail density,
- land use diversity factor and
- a rating of land use, density and urban form.

As especially shown by the actual meta-analysis of 50 empirical studies, land use mix, the balance of jobs and population and the distance to stores is of high importance for the amount of vehicle miles travelled by enhancing both, walking as well as the use of public transport.

The following table shows weighted average elasticity found in various empirical studies on the interrelation between built environment and transport. Referring to the issue of diversity, the highest effects are shown for walking in general and the distance to store in detail (according to these findings e.g. by a reduction of distance to store of about 10%, an increase of walking of about 2.5% can be expected).

Table 2: Findings on the importance of diversity on vehicle miles travelled, walking and public transport use

	Vehicle miles travelled	Walking	Public transport use
Land use mix	-0.09	0.15	0.12
Job-housing balance	-0.02	0.19	-
Distance to store	-	0.25	-

Source: Ewing and Cervero 2010

In a more European context, also Wegener/Fürst (1999) found correlations verified between neighbourhood design and trip length as well as with modal choice[11]. Thus it was shown that:

- 'Traditional' neighbourhoods show significant higher shares of public transport and environmental friendly modes of transportation (although it was mentioned, that design factors are less important than socio-economic factors)
- Those traditional neighbourhoods account for shorter trips than car-oriented suburbs.

Additionally, an appropriate population density has been proved to be important for walking and cycling in most of the studies.

[11] Though also Wegener/Fürst (1999) used findings from European studies as well as US findings.

General guiding principles referring to functional mix of land use

Following main principles can be formulated based on available literature:

- ***Efficiency due to energy services by common supply***
  - Consideration of heat sources and location of potential heat consumers in the range of the heat source (e.g. waste heat)
  - Strive for a combination of residential and working population (for a balanced urban density during the day) providing with better options for public transport provision
- ***Minimising VMT, environmentally friendly mobility***
  - Aiming at a mix of functions (shorter distances travelled (to work), local supply options)

2.2.4 Green Spaces/ Open Spaces within the Urban Environment

Minimising losses of (heat) energy	*Maximising passive (heat) energy gains*	*Active use of decentral renewable energy*	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

Green and open spaces provide a number of chances in the complex structures of cities and even of villages.

One important task of unsealed surfaces is their ability to influence the microclimate in urban structures (mainly due to evapotranspiration of vegetation) and lessen heat island effects, thus reduces the need for energy input for space cooling [12]. In this context a certain contradiction has to be taken into consideration (Ståhle 2008). On the one hand less dense building types as i.e. single family houses account for less ground sealing (about 20-50%) than multifamily buildings (about 50-75%) and thus in average leads to a higher share of open space per hectare (Siedentop/Schiller et.al. 2006a). On the other hand – regarding at the entire municipality – the spread of such not densely developed areas increases the sealed surfaces per capita and therefore as well the total area of sealed surfaces and built up land is larger (see also figure 14: Surface-to-volume ratios of different building shapes and according land consumption).

Green spaces provide with the possibility to use shading of buildings by trees and plants to reduce the exposition to the sun. Nevertheless, in this case, the potential

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12 In the classification at hand, the necessity of cooling has been defined as 'energy loss', thus the effect of green open spaces to lower the demand for space cooling is defined as a special case of minimising losses of energy.

conflict with the use of passive and active solar energy has to be taken into consideration.

On the opposite, green open spaces may enable a higher share of unshaded buildings and thus enhance passive solar energy gains as well as active use of solar energy especially in densely built up areas. Thus, another aspect of green open spaces is the possibility to use those surfaces for the installation of decentral renewable energy sources.

As Genske et.al. (2009) have shown, even in urban contexts there are considerable possibilities to make use of decentral renewable energy sources within the borders of an urban structure. As good practice examples amongst others there are presented a solar thermal appliance along a noise barrier, small wind turbines and an energy wood as temporary use of land (further examples are shown not only at green open areas).

Referring to photovoltaics, large photovoltaic installations might provide shading in parks (see figures below as examples) and there are divers architectural ideas and products for green roofs providing with both evapotranspiration by vegetation and the use of roofs for energy production as e.g. green roofs covered by photovoltaics (allowing for additional synergies due to an increase of efficiency because of lower temperatures).

Figure 9: Multiple shift usage – shading by photovoltaic panels and sheep paddock with photovoltaic installation

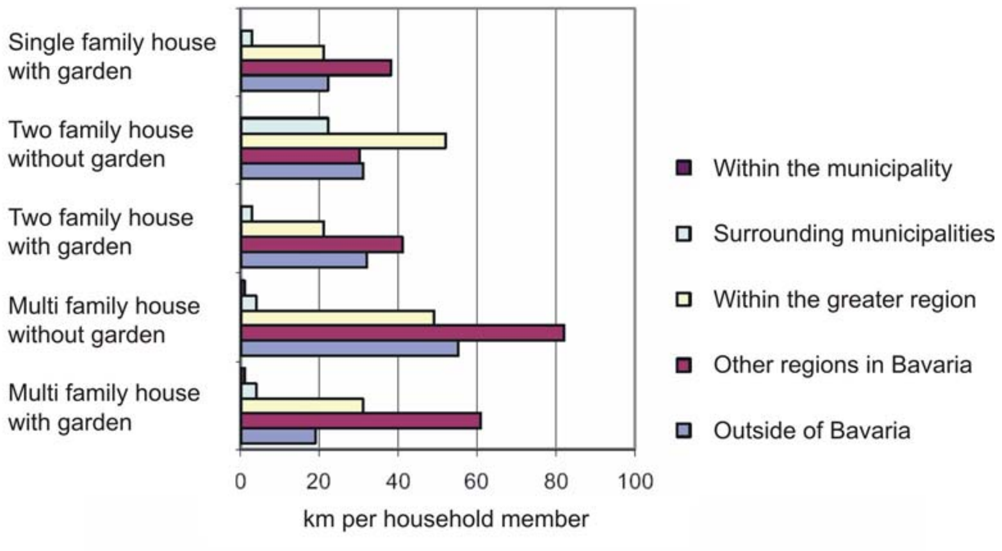
Sources: http://www.ertex-solar.at; http://media.repro-mayr.de/44/89544.jpg

Finally there has to be stated an influence of green space and accessibility of attractive leisure areas for minimising vehicle miles travelled. This is especially important for larger cities and agglomerations with population not owning private gardens.

It has been shown in studies, that there is a correlation between the accessibility of (private and/or public) green urban space provided and leisure transport (especially important for VMT).

Tappeiner et.al. 2002 present the relation between single-family houses and multi-family houses with and without private gardens and kilometres travelled per month in order to spend leisure time. As shown in the following figure for the agglomeration of Munich, persons in single and double family houses with garden travel less (for leisure activities) than persons living in the same housing category without private garden. Unfortunately there were no criteria included for the attractiveness of nearby public open space.

Figure 10: Kilometres travelled per month for leisure trips by housing type (for the example of Munich agglomeration)



Source: Tappeiner et.al. 2002 (original source: Kagermeier 1997), own translation

In general, persons with private gardens or access to attractive leisure areas nearby tend to travel less, at least in urban areas. This is especially true for weekend trips. A combination with attractive cycle paths and walking links optimises the attractive-ness for using surrounding areas for recreation without need of car use.

Another factor to be considered is the accessibility of leisure facilities due to regional location and hierarchy of the inhabited city or village. Microcensus studies from Switzerland conclude, that distances driven for leisure purposes in total are higher in small villages located peripheral than in more centrally located and thus more densely developed areas (ARE 2006). Hence VMT for leisure purposes is not only dependent on the accessibility of green areas, but also on the regional location of housing structures and the accessibility of leisure infrastructure in general.

Finally the comparingly low share of leisure transport by car of about 13% (compared to the total amount of person km) has to be taken into consideration (BMVIT 2007)[13]. Thus concluding it can be stated that there may be a contribution of green space availability on avoidance of VMT, but its influence on VMT is difficult to be quantified and is only of minor importance in total (compared to all travel purposes).

General guiding principles referring to green spaces/ open spaces within the urban environment

Following main principles can be formulated based on available literature:

- ***Minimising losses of (heat) energy***
    - Sufficient green space within the built up urban area, consideration of green arrows and green connections throughout the built up area (heat island effect)
    - Use of shading for less heat accumulation
- ***Maximising passive (heat) energy gains***
    - Considering solar use in location of green urban space
- ***Active use of decentral renewable energy***
    - Considering use of renewable energy (mainly solar use) in location of green urban space
- ***Minimising VMT, environmentally friendly mobility***
    - Sufficient green space within the built up urban area (as alternative to car travel leisure activities) and for higher quality of life

[13] According to a survey in the agglomeration of Salzburg in 2004, the share of passenger traffic performance (person km) for leisure purposes reached about 22% (all modes), about 13% of total km travelled were done by cars (share person km of drivers on total person km). In contrast commuting to work amounts to about 23% of passenger traffic performance (person km) by car drivers. Additionally, following purposes are included (for 100%, all modes): business trips (13%), school/education (10%), shopping 12%, others (12%) (BMVIT 2007).

2.3 Local construction plans – density and urban design

2.3.1 Urban density

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	*Active use of decentral renewable energy*	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

As density is an **important indicator** for divers interrelationships referring to energy demand of the built environment and in transport issues, it is essential to define the range of urban forms, which are linked to a certain density level.

Density is defined by different key figures according to the relationship described. Thus dependent on the figure used for defining density, certain information can be given on the situation within a specific area.

The following specific values are important for measuring density, describing or at least indicating different characteristics of an area:

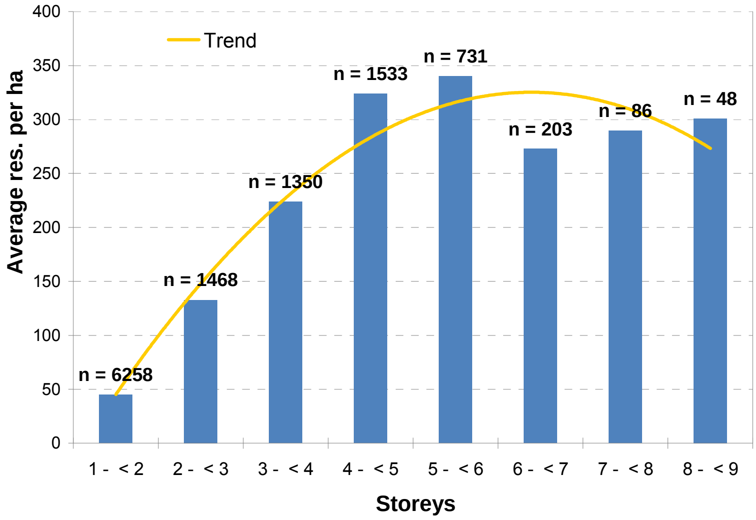
- Population density / density of inhabitants and jobs (also called urban intensity), important parameter for public transport provision and local supply issues)
- Density of the built environment and design of urbanised space (e.g. proportion of sealed ground (LBR land to building ratio), important indicator for the issues of microclimate and of heat islands and for optional use of open land for local renewable energy production (e.g. near surface geothermal energy)
- Density of living space – e.g. floor space index (FSI), important indicator for the estimation of building dimensions including effects of shading and important for district heating networks (together with the thermal standard of buildings)
- Heat density is a product of living space, thermal standard in terms of heat demand per m^2 and climatic factors, it is an important parameter for district heating networks

The relation between population density and floor space index (FSI) is an indicator for building structures saving of ground space due to the height of buildings.

As shown in the following figure (for residential buildings in Berlin), up to a certain level of storeys (and thus higher FSI) population densities increase according to the increase of height of the buildings. After exceeding this certain number of storeys (and height) density does not further increase in existing urban structures (in average). This is the case mainly due to restrictions because of consideration of quality of life criteria, referring requirements on distances between buildings (in relation to height) e.g. in terms of access to sunlight.

Taking the example of Berlin[14] as a benchmark, this leads to the assumption, that – from a population density perspective – 4-6 storey buildings seem to depict the optimal urban form providing with a high level of quality of life together with higher population density.

Figure 11: Resident density in proportion to the average storey number per block (only blocks with residential use, Berlin)

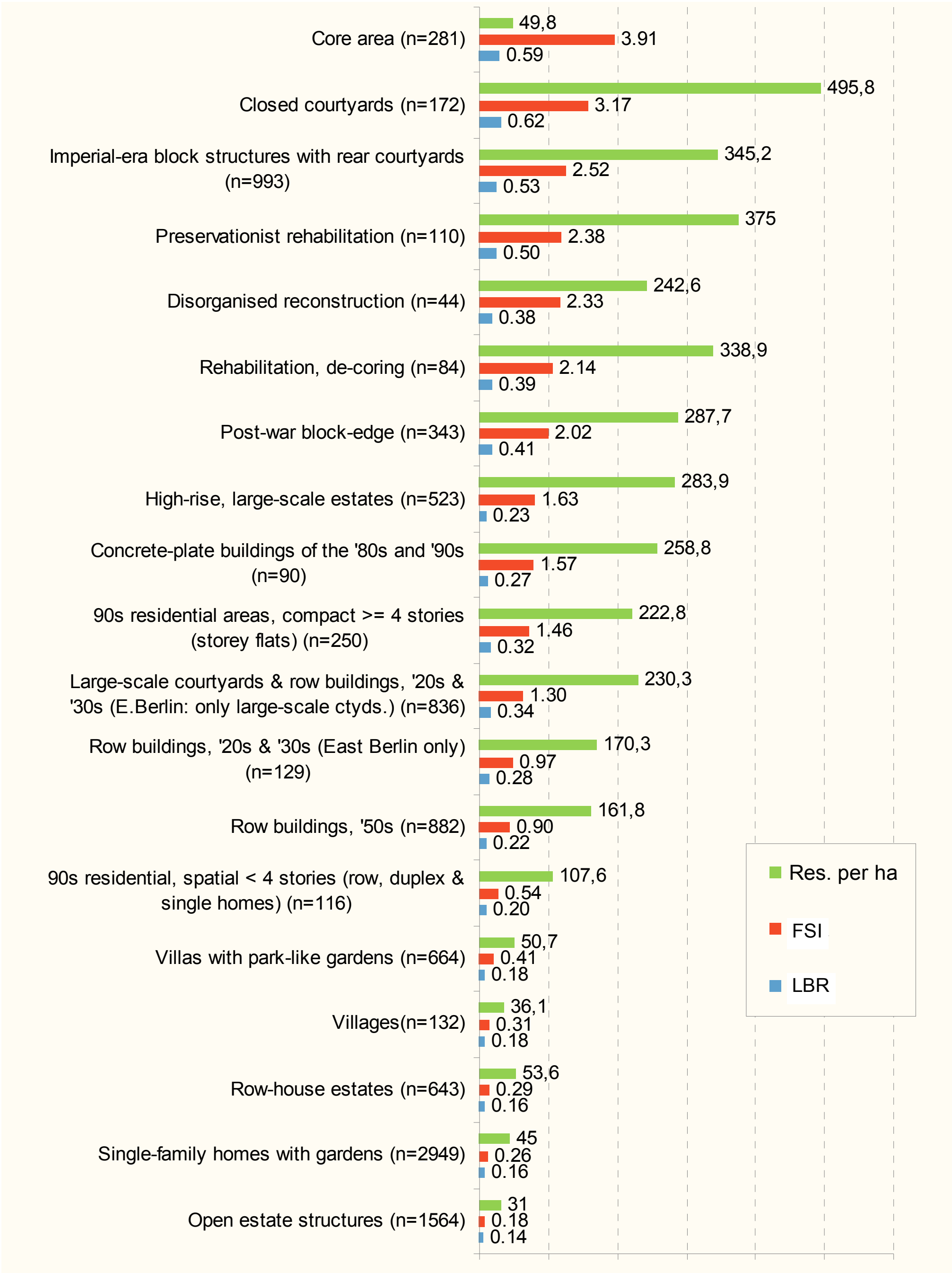


Source: Senate Department for Urban Development Berlin 2010

According to these density levels in context with the number of storeys, this general relation can also be shown for types of urban form (or urban structures). The following figure (again for the example of Berlin) shows the different values according to population density (residents per hectare), land to building ratio (LBR, built-up proportion of a lot) and floor space index (FSI, floor area/living space per ground area). As it can be shown, population density hardly exceeds 400 persons per hectare (with exception of the very densely built old urban form of closed courtyards), while the land to building ratio continuously increases.

[14] It can be stated, that urban form types in Austria are in principal similar to those, shown for Berlin.

Figure 12: Resident density, FSI and LBR of the different urban structure types in comparison (Berlin)



Source: Senate Department for Urban Development Berlin 2010

Referring to the data from Berlin a high-level population density for this region seems to be reached at an FSI of about 1.5 to 2. For Munich, a relatively high population density for residential areas is stated to be reached at an FSI of 1.2 (Hutter/Westphal/Siedentop et.al. 2004). Above this value of FSI higher population density and according additional saving of ground space is only possible to a very little extent (considering the conditions and legal requirements in Berlin respectively Munich).

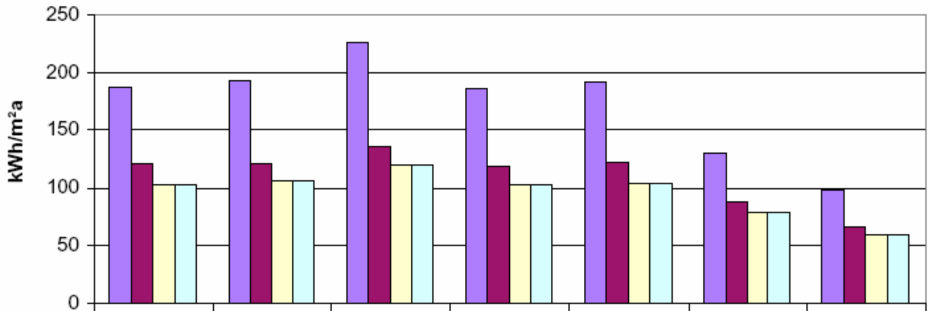
The relation between FSI and population density and thus the possibility for saving ground space additionally is depending on the size of living space per person (depending again on the cost of living space and the economic welfare of the areas inhabitants). According regulations but also living space per person and the level of (accepted) population densities differ from city to city respectively from country to country. Whereas population densities in Northern European countries are comparatively low (e.g. UK, Sweden) countries of hot climate conditions usually show considerably higher average densities (e.g. Greece, Italy) (Schremmer et.al. 2009).

Building types and residential heat demand

Construction plans define options for types of buildings to be constructed in a specific area mainly due to the regulation of building heights and the share of a plot respectively the area allowed to be built up.

The following figure presents the average energy demand of different housing types for space heating. Clearly, single-family houses need more energy for space heating than other more densely populated building types. This is especially true for buildings constructed before 1980, whereas the difference in energy demand for space heating between building types lessens for new houses (due to still advancing insulation standards).

Figure 13: Space heating energy demand per m² heated floor area (useful energy) in Austria classified by the building types and building age



	before 1919	1919 - 1945	1945 - 1960	1961-1970	1971 - 1980	1981 - 1990	after 1991
SFH	188	193	226	186	191	130	99
MFH-S	121	121	136	118	122	88	67
MFH-B	103	106	120	103	104	78	60
NRB	103	106	120	103	104	78	60

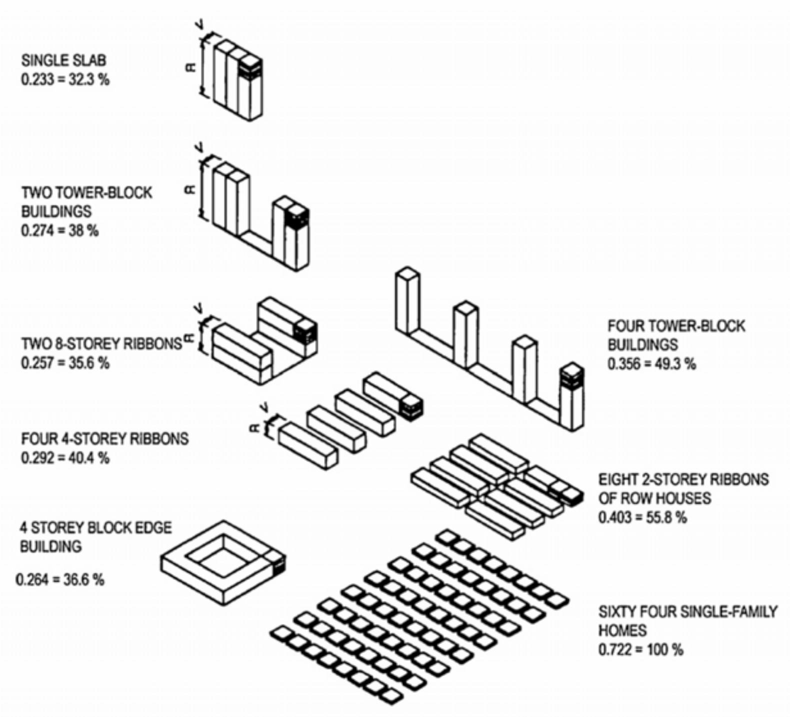
Note: SFH: single and (two) dwelling buildings, MFH-S: small multi-family buildings, MFH-B: large multi-family buildings, NRB: non- residential buildings

Source: Wirtschaftskammer Österreich, 2007, Original data source: Jungmeier, et al. (1996)

As shown in other analyses (Stadt Münster 2003, Landeshauptstadt Düsseldorf 2007, BMVBS 2007), even a housing type providing with only little more density (terraced housing) is offering the possibility of considerable lower space heating demand in average.

This relationship between building types and energy demand for space heating is caused mainly by transmission losses through the envelop of buildings depending on different ratios between surface and volume of buildings. Whereas single-family houses show a less favourable surface-to-volume ratio, this ratio is most favourable for buildings between 3-5 storeys. For higher buildings there is only very little improvement possible. According to this ratio most favourable blocks of multi-family houses show a length of about 30-50m and a width of 12-14m (Stadt Essen, 2009). For younger buildings the surface-to-volume ratio seems to loose importance mainly due to higher thermal insulation standards, still there are considerable differences to be stated also for new houses (see shown also in fig. 13). The differences of this relation between surface and volume are shown in the following figure on different building shapes for equal building masses of 64 flats each.

Figure 14: Surface-to-volume ratios of different building shapes for 64 flats



Source: Wende et.al. 2009 (original source: DIFU 1997)

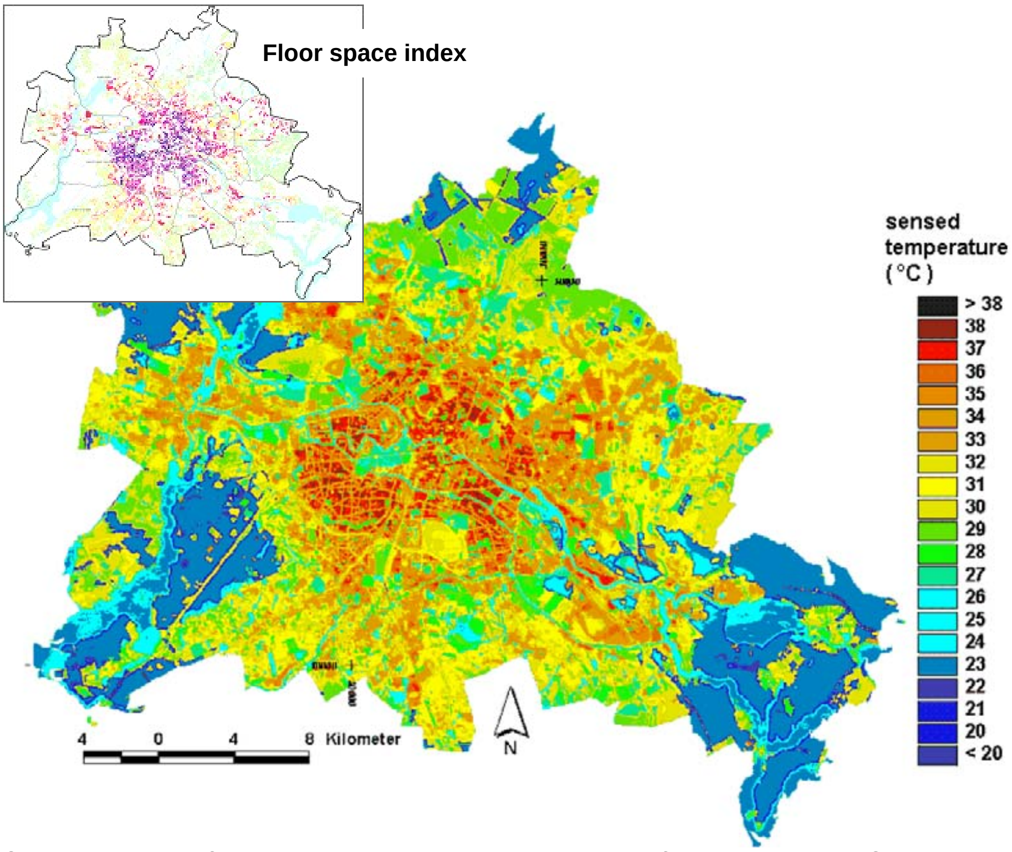
Density of built structures and urban heat islands

Urban heat islands are effects mainly provoked by high densities of buildings and surface sealing. Overall, heat storage by buildings and low ventilation rates lead to higher temperatures in densely built up areas with two different effects to be considered:

- In the cold season the effects of storing solar energy in the building envelops and protecting built structures from exposition to wind may help to reduce the energy demand for heating. EnergieAgentur.NRW (2008) is pointing out heat savings of urban heat islands up to -15%.
- In summer the same effects may lead to overheating of high-density structures affecting urban environments and resulting in an additional energy demand for cooling (especially for office buildings of low thermal standards).

The following figure shows a comparison of the built structures (indicated by the floor space index) and temperature levels in Berlin at a summer day. It clearly presents a correlation between higher densities and higher temperature levels (the issue of ventilation is presented in chapter 2.3.3 'Consideration of wind regime').

Figure 15: Floor space index and temperature levels in city structures on a summer day (for the example of Berlin)



Sources: Wirtschaftsministerium Baden-Würtemberg/ Amt für Umweltschutz Stuttgart (2008) and Senate Department for Urban Development Berlin 2010 (floor space index)

Density and the use of decentral renewable energy sources

In terms of the use of renewable energy there are conflicting relations to be considered, as high densities minder options for the use of renewable energy especially in terms of solar energy[15] and near surface geothermal energy (heat pumps).

Less open space of building types with high urban density also lessens the possibility for near surface geothermal energy use. An option for near surface geothermal energy use usually exists in villages or small cities and less densely developed outskirts of larger cities. Due to the fact that there is a need of about 25 m^2 per kW[16] (Dötsch et.al. 1998), it is obvious that this type of renewable energy supply can be an option only in less densely developed areas, e.g. in single family house quarters with private gardens or possibly in areas of small multi-family houses with large common green space.

Options for district heating networks

Under certain conditions (especially minimum densities, see below), district heating networks offer good options for lower non-renewable primary energy demand by higher efficiencies and thus less CO_2 emissions due to heat provision. This is especially the case if renewable energy sources are used e.g. by heat production with biomass, biogas and waste or due to the direct use of waste heat (Schweizerischer Ingenieur- und Architektenverein 2004, GEMIS 4.6 2010).

Table 3: Average primary energy demand (non renewable) and CO2 emissions for heat provision by varying heat production and energy carriers

Heat production by	CO_2 equivalent (g/kWh final energy)	Cumulated, non renewable primary energy use (kWh primary energy/kWh final energy)
Heating oil (boiler)	376	1.38
Natural gas (boiler)	290	1.33
Wood pellets (boiler)	25	0.09
District heating mix	254	0.90
District heating (wood based)	65	0.25
Small scale district heating (block heating biogas plant)	99	0.34

Source: GEMIS 4.6 2010

15 All aspects of the use of active and passive solar energy (including those referring to density issues) are referred to in the following chapter 2.3.2 'Solar orientation of buildings'.

16 It can be stated, that the size of area needed for a conventional building is about 1.5-2 times the heated living space.

District heating systems show a $CO_{2\ (equivalent)}$ -factor of about 65-250 g/kWh final energy, depending on the energy source used, the size of the grid and the distance to the heat plant. Compared to oil driven boilers, this is a reduction of at least about – 32% (district heating mix) and up to -83% (wood based heat plant). In comparison with natural gas, there is still an average reduction of – 12% (district heating mix) and up to -78% (wood based heat plant). Additionally, by change from heating oil or natural gas boilers to district heating systems a similar reduction can be achieved in terms of non-renewable primary energy use (fossil fuels).

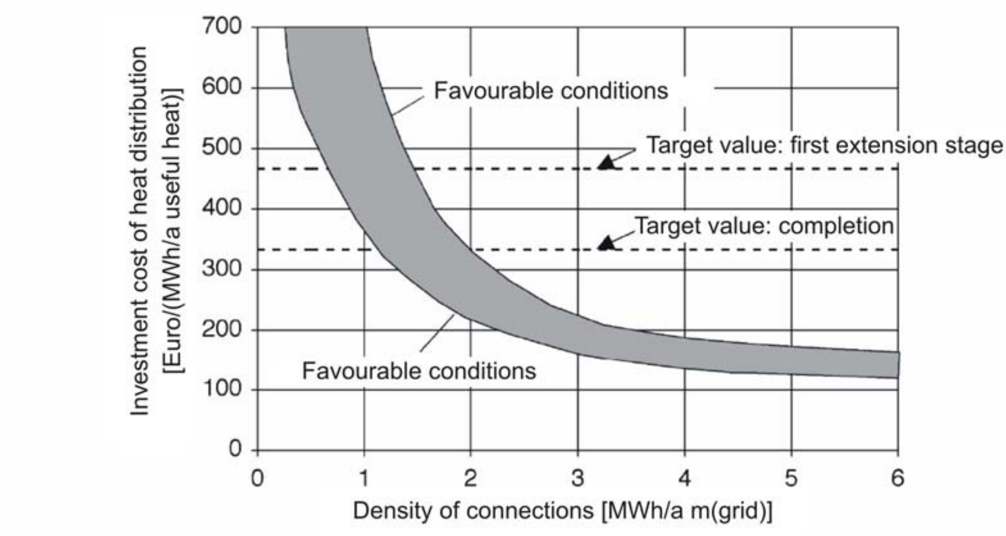
There are certain conditions to be considered in planning and implementing district heating networks in urban development areas as well as in already built up areas.

Due to considerable heat losses within the distribution network, the length of the network between users is of utmost importance. The higher the heat demand within a certain area (heat density), the better are the options for realising an efficient (and economically feasible) district-heating network. In general, it is much more difficult to implement district heating systems in built up areas in contrast to new developments, due to already existing (usually individual) heating systems.

In practice the implementation of district heating networks is based on considerations concerning economic feasibility. Nevertheless, usually there are uncertainties left during the planning phase. The following figure shows the relation between investment costs and the demand of and distance between heat consumers (MWh per year and meter of the network) for the example of Switzerland. Many district heating systems work under favourable conditions but at the same time, there are a lot of systems with much higher costs for one MWh provided heat per meter of the grid.

Overall, district heating networks should reach a value of at least about 460€/MWh useful energy and a connected heat demand of about one MWh per year and meter of grid in the first phase of implementation and about 330€/MWh useful energy and a connected heat demand of around 1.5 MWh per year and meter of the grid after the overall completion of the network.

Figure 16: Specific investment costs of heat distribution in relation to the heat demand of connected consumers (consumed heat density)



Source: Arbeitsgemeinschaft QM Holzheizwerke 2004, own translation

Thus in case of networks showing less favourable ratios other priorities or unexpected difficulties in the realisation phase might have led to - in terms of economy as well as referring to heat losses - less favourable situations (e.g. less connections realised than signalised in the first conversations with potential clients, delay in expected urban development or decrease of heat demand due to building renovation).

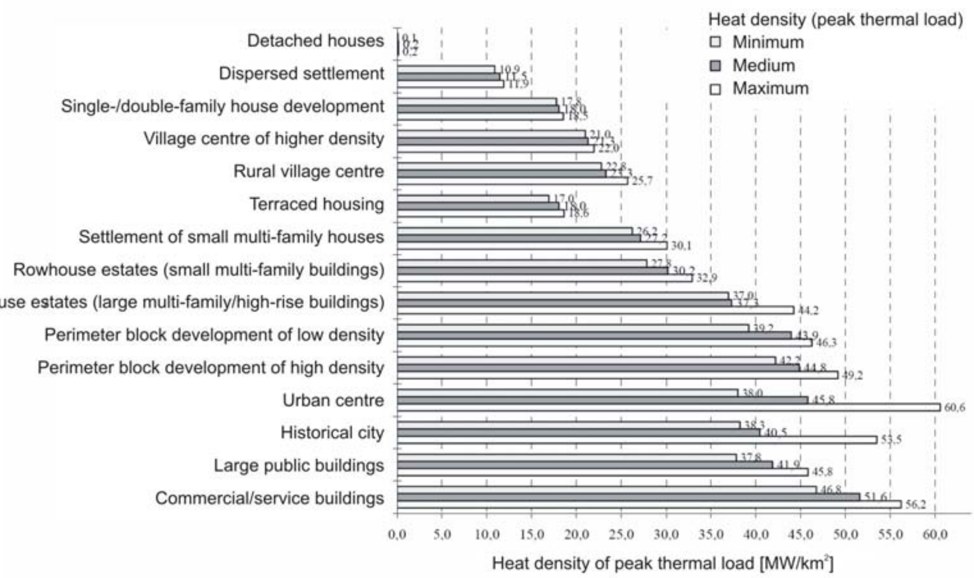
As shown above, a minimum heat density of an area supplied with district heat has to be quoted as an important factor for the economic performance of a network (as well as for heat losses to be expected).

The heat density of an area is a function of the heated living space in that area which is connected to the district-heating grid[17] together with the volume-to-surface ratio and the thermal quality of the respective buildings (and according heat demand per m^2 heated living space) as well as climatic factors. Due to the fact, that different settlement structures differ in terms of volume-to-surface ratio but also in terms of average living space per capita, it is important to look not only at population densities but to consider those differentiations between areas of specific settlement structures.

The following figure presents the range of minimum to maximum heat densities (peak thermal load) of different types of settlements (in Germany).

[17] In Austria there is no possibility to define areas of obligatory connection to the district heating network (purchase commitment) by spatial planning.

Figure 17: Heat density in different settlement structures

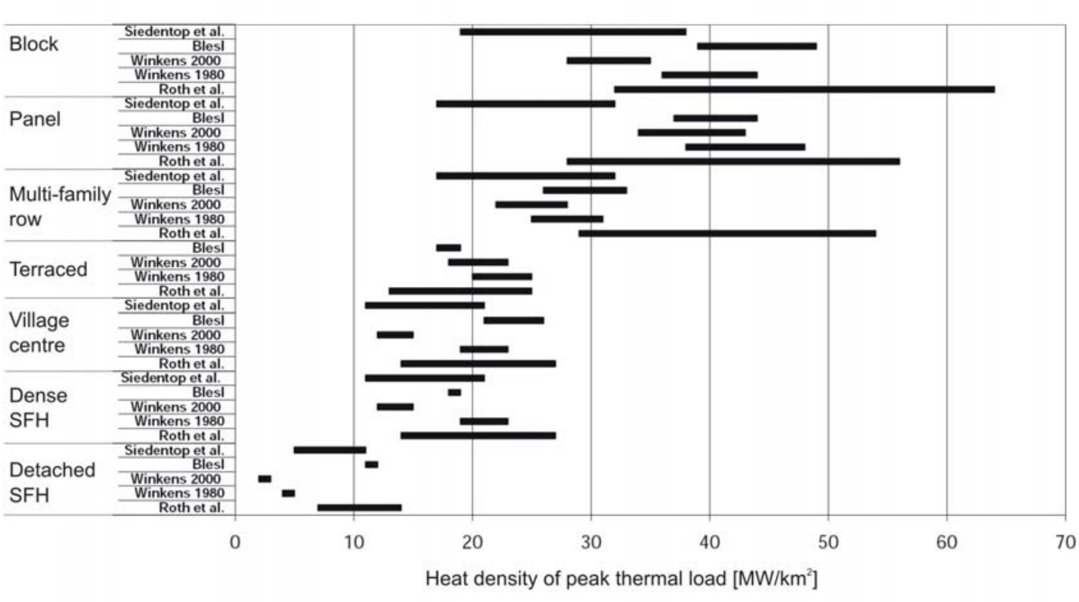


Source: Blesl 2002, own translation

This empirical analysis (Blesl 2002) considers a differentiation between buildings of different construction periods and according building standards only to a minor extent (historic city as a specific category). Nevertheless, an important relation between settlement structures and a range of heat densities can be clearly shown.

A meta study done by Westphal 2008 shows the range of appraisals from different studies (including Blesl 2002) in terms of heat density (peak thermal load) of different settlement structures. Overall this analysis indicates similar differences between settlement structures, but final appraisals and research findings differ widely (following figure).

Figure 18: Heat density (peak thermal load) of different settlement structures, comparison of findings

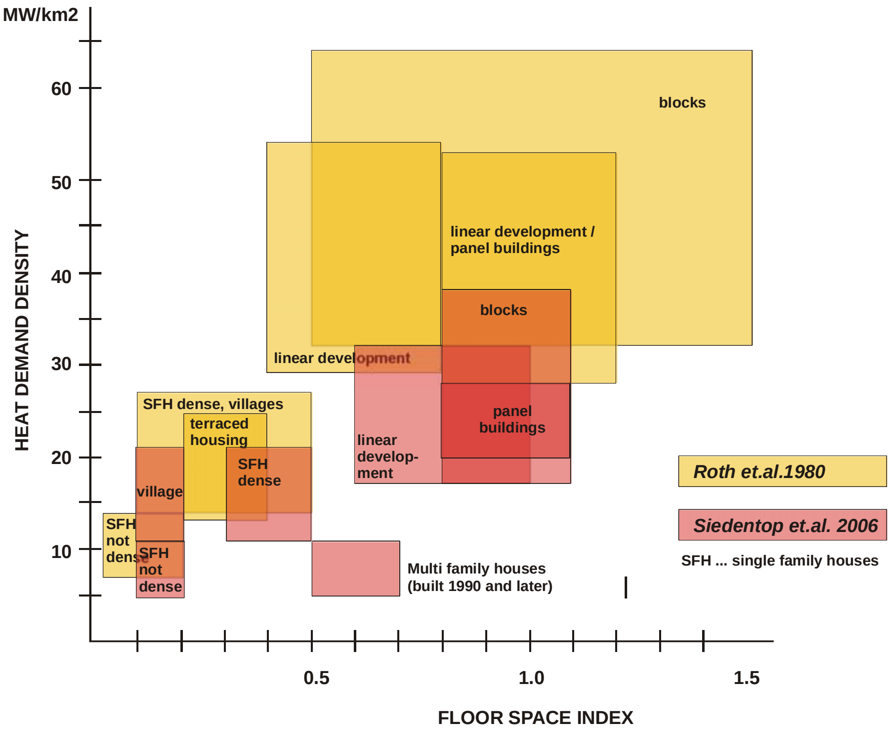


Source: Westphal 2008, own translation

The following figure presents the relation between settlements of specific building types including information on floor space indexes and according heat densities (peak thermal load) for an analysis of the year 1980 and from a recently published analysis.

In this figure, especially the range of the relationship between FSI and heat density as well as the general reduction of heat demand over the past decades is presented (mainly due to thermal renovation and new buildings with considerably lower energy demand). Whereas i.e. the heat density (peak thermal load) in areas of blocks exceeded 60 MW/km^2 in 1980, it is stated to be less than 40 MW/km^2 in 2006 (Westphal 2008).

Figure 19: Floor space index of different building types/settlement structures in Germany and average densities of heat demand (peak thermal load)



Source: Westphal 2008 (redrawn)

Similar to different appraisals of the heat demand of specific settlement structures, it is difficult to recommend a necessary minimum heat demand density for the economic supply of district heat in general. According to Westphal (2008), there are recommendations due to economic analysis of a necessary minimum heat density (peak thermal load) for long-distance district heat networks between about 40 MW (analysis 1987) and 25 MW (analysis 2006) or a minimum floor space index of about 0.7 FSI. The minimum heat density is stated to be lower for small scale, local district heating systems (e.g. checklist Hessisches Ministerium für Umwelt, Ländlichen Raum und Verbraucherschutz 2006).

In terms of spatial planning and the construction of a district-heating network, there is a number of important issues to be analysed before a decision pro or contra the construction of a district-heating grid within a specific area. Some authorities have launched checklists for this decision to support the decision process in a constructive way.

As indicators for a favourable situation in terms of the establishment of a district-heating grid the following conditions can be stated (Hessisches Ministerium für Umwelt, Ländlichen Raum und Verbraucherschutz 2006):

- Heat demand of about 250-300 MWh/ha/a (for small scale, local district heating systems), this refers to a necessary minimum density provided of at least dense single family house and terraced housing areas of construction periods before 1995[18]. For new developments, the supply of (even densified) single-family areas with district heating systems seems increasingly difficult.

- Areas of similar (high) energy demand for space heating (e.g. areas built up in the 1950s and 1960s).
- Areas of buildings with similar construction period stated to change their heating systems soon (due to end of lifetime considerations)
- Public buildings with high space heating demand in the area
- Areas without supply with natural gas
- Areas with problems in terms of emissions (argument for district heating system to enhance the aerial situation)
- Situation in terms of biomass supply (wood and waste wood) and supply with waste (e.g. agricultural waste and/or food residues for biogas production)

Referring to spatial planning there are two indicators stated to be of importance: primarily this is the minimum heat demand (due to building types of higher densities within a contiguous built up area of a minimum size), secondly as well functional mix at least provides with a chance for high heat demand by public and/or commercial clients, which might support opportunities to supply an area with district heat.

Options for public transport and slow modes

Relating to mobility urban density (population and jobs) is a crucial indicator for different options (often with an amplifying effect together with mixed functions).

Kenworthy and Newton have emphasised the interrelation between urban density and motorised transport (indicated by petrol use) for cities worldwide (Wegener 1999). Nevertheless, in literature, this hypothesis of causality of average urban density (for cities in total) and car use (petrol use) is highly discussed[19].

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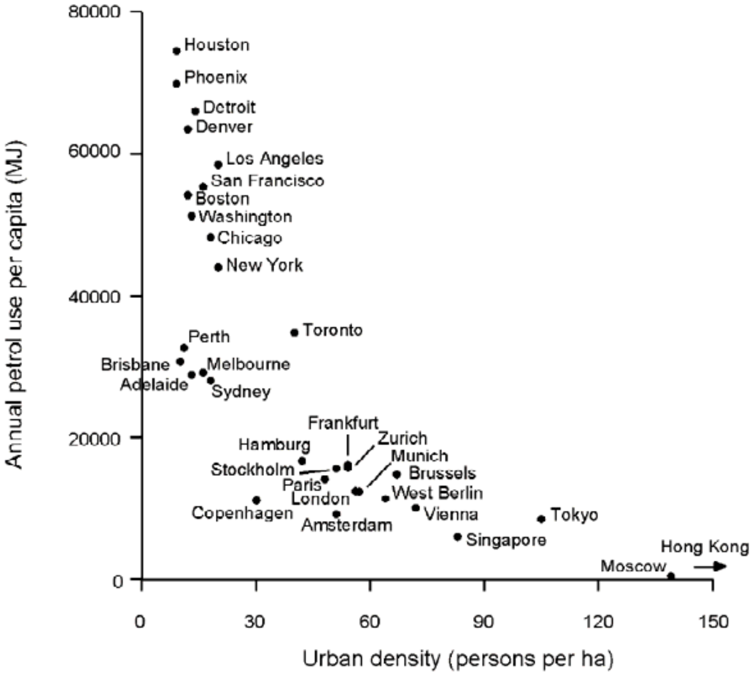
[18] Examples from an empirical analysis in Germany (Hessisches Ministerium für Umwelt, Ländlichen Raum und Verbraucherschutz 2006): A yearly heat demand density of about 550 MWh/ha corresponds to:

- 29 single family and terraced houses and 20 multi family houses of construction period 1976-1995 within a built up area of 4.3 ha;
- 130 single family and terraced houses of the construction period 1985-1995 within a built up area of 9.3 ha;
- 100 single family and terraced houses of the construction period 1976-1985 within a built up area of 8.5 ha.

[19] It has been demonstrated, that similar results can be achieved, when opposing petrol prices relative to per-capita income (as underlied in the study) instead of urban density. Thus, the question of urban density or petrol prices being decisive for the curve shown by Newman and Kenworthy is highly discussed. In this context it can be assumed, that is it were those higher petrol prices, which led to higher densities of built up areas in the past and thus to cities with higher densities. Nevertheless, in a post-fossil future, such cities and their inhabitants will be able to

Figure 20: Urban density and petrol use at an overall scale



Source: Kenworthy/Newton (original source: Wegener 1999)

In contrast to the relation between average municipal densities (in total) and petrol use per capita, the assumption of a causality between residential (or population and job) density of smaller units (e.g. urban quarters or villages) and distances travelled by private car respectively public transport use is put into question much less (e.g. Norman/MacLean/ASCE/Kennedy 2006 Wegener/Fürst 1999, Cervero and Kockelman 1996, Newman and Kenworthy 2006, Litman 2010, Ewing and Cervero 2010). Also Wegener/Fürst (1999) conclude that this interrelationship is widely confirmed (following table).

adjust themselves to a changeing framework more easily and efficiently than less densely developed cities.

Table 4: Impacts of density on transport in empirical studies

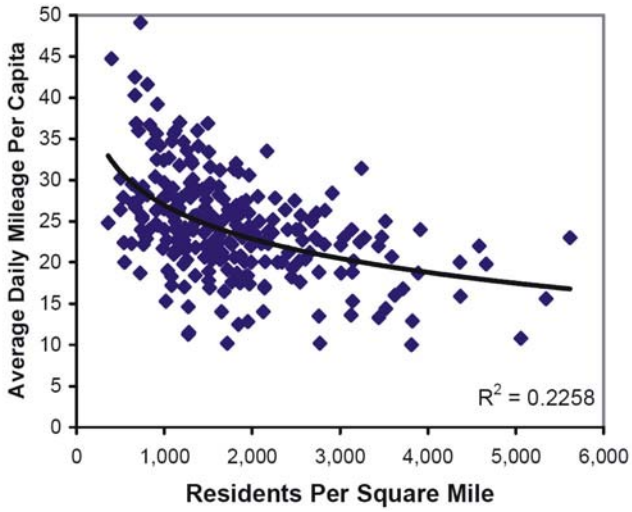
Direction	Factor	Impact on	Observed impacts
Land use ⇓ Transport	Residential density	Trip length	Numerous studies support the hypothesis that higher density combined with mixed land use leads to shorter trips. However, the impact is much weaker if travel cost differences are accounted for.
		Trip frequency	Little or no impact observed.
		Mode choice	The hypothesis that residential density is correlated with public transport use and negatively with car use is widely confirmed.
	Employment density	Trip length	In several studies the hypothesis was confirmed that a balance between workers and jobs results in shorter work trips, however this could not be confirmed in other studies. Mono-functional employment centres and dormitory suburbs, however, have clearly longer trips.
		Trip frequency	No significant impact was found.
		Mode choice	Higher employment density is likely to induce more public transport use.

Source: Wegener/Fürst 1999

As an actual meta study from Litman (2010) points out, it is the conclusion of a number of studies (especially from US) that urban density tends to reduce vehicle miles travelled and to increase the use of non-motorised mobility considerably.

The following figure shows this relation between residential density and vehicle miles travelled for US urban areas. It clearly indicates a flattening curve with higher reduction of VMT between a density of 500 to 1000 residents/sqm than between 1000 and 2000 residents/sqm (and so on).

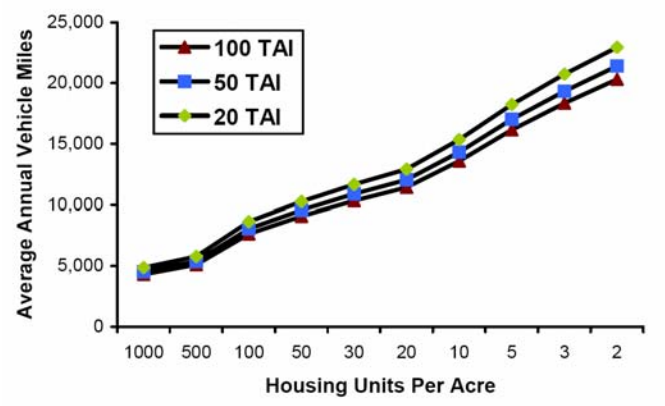
Figure 21: Density versus vehicle travel for U.S. urban areas



Source: Litman 2010 (original source: FHWA 2005)

Including the supply with public transport (in this case accessibility and supply of 'public transport seats' per hour), it can be shown, that an attractive supply with public transport has an effect on VMT as well, even if it is much lower than the influence of higher density.

Figure 22: Residential density and annual VMT per household



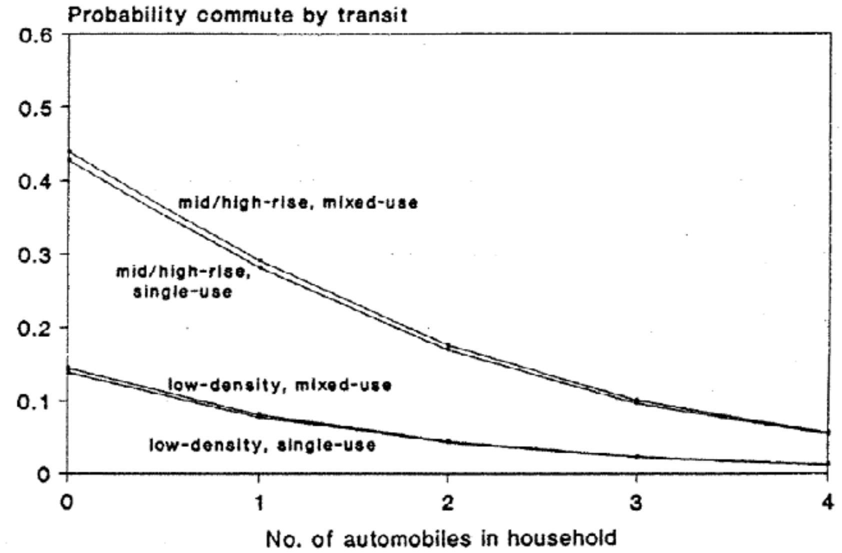
Note: TAI (Transit Accessibility Index) - 50 vehicle seats offered by public transport per hour within a shed of about ¼-mile (or ½-mile for rail) averaged over 24 hours.

Source: Litman 2010 (original source: Holtzclaw 1994)

Ewing et. al. 2007 present a notable correlation between different density levels on the probability for the use of public transport (transit) on the basis of a statistical analysis of about 45,000 households in the USA, while considering functional mix as an additional variable. Whereas the probability in mid/high rise areas (with higher urban densities) is about 45% (nearly independent from the mix of functions), this value is about 15% for low-density areas.

The following figure shows the cited findings together with another important factor, namely car ownership rates, which are affecting the probability of commuting by public transport considerably.

Figure 23: Effects of density on modal choice for commuting



Source: Ewing et.al. 2007 (original source: Cervero 1996), based on data for more than 45,000 U.S. households

Handy (2005b) presents findings on elasticity with reference to a study by Ewing and Cervero, which point out effects of changes of built environment characteristics on energy demand for mobility[20]. According to these findings (elasticity of 0.03 - 0.05) a 10% change of the built environment characteristics (e.g. density increase) is related to an about 0.3-0.5% decline of trip frequencies and vehicle miles travelled. The most recent study of Ewing and Cervero (2010) is concluding with similar findings in terms of elasticity affected by population densities. They present elasticity of density of -0.04 in terms of VMT. In return they present positive elasticity by density increase for walking (population density: 0.07, job density 0.04) and for public transport use (mainly population density: 0.07, whereas job density seems to be of secondary importance: 0.01).

In general this seems rather low, on the other hand it has to be taken into account, that i.e. a doubling of residential density is easily possible (in theory) for a large number of residential areas (especially with reference to single family house areas).

Finally it has to be stated, that there is another issue in context with urban densities and public transport options, which is car dependence. Favourable options for public transport and slow transport modes by adequate densities are important to provide the possibility of environmental friendly transport modes for the future. In case of a

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[20] Considered characteristics of built environment: Local density of residential and working population, local diversity as jobs-population balance and local design defined as a combination of sidewalk completeness, route directness and street network density.

Effects on energy demand for mobility - considered parameters: Trip frequency and vehicle miles travelled (Handy 2005b) rapid increase of fuel prices, this is a chance to avoid serious consequences due to energy poverty (at least in terms of transport, e.g. commuting) and provide for socially fair conditions in a medium to long-term development.

General guiding principles referring to density

Following main principles can be formulated based on available literature:

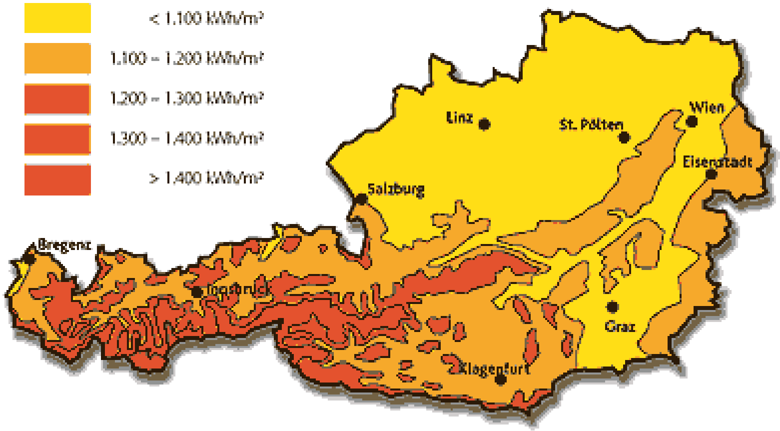
- ***Minimising losses of (heat) energy***
  - Consideration of building type related energy demand for space heating and their density (heat islands)
- ***Active use of decentral renewable energy***
  - Considering options for near surface geothermal energy
- ***Efficiency due to energy services by common supply***
  - Options for district heating systems
  - Densification at certain locations (locate heat consumers in the vicinity of heat sources)
  - Options for public transport
- ***Minimising VMT, environmentally friendly mobility***
  - Options for local supply (small centres and short distances)

2.3.2 Solar orientation (of buildings)

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

Solar radiation is providing a considerable amount of energy, which can be used for energy (heat) provision in buildings passively and actively. In Austria solar radiation ranges between about 1,000 – 1,500 kWh/m^{2}a at horizontal surfaces. Higher solar radiation has to be stated in the western, mountainous areas of Vorarlberg, Tyrol, Carinthia and partly Salzburg.

Figure 24: Solar radiation in Austria



Source: http://www.solarwaerme.at/Sonne-und-Energie/

Overall, in all Austrian regions good conditions for the use of solar energy can be stated. Nevertheless, at a local scale differences between locations have to be considered mainly due to topography (s.f. chapter 2.2.1).

The chapter at hand is dealing with two important topics referring to the aim of maximising passive energy gains as well as in terms of the possibilities for active use of available solar radiation. Those topics are:

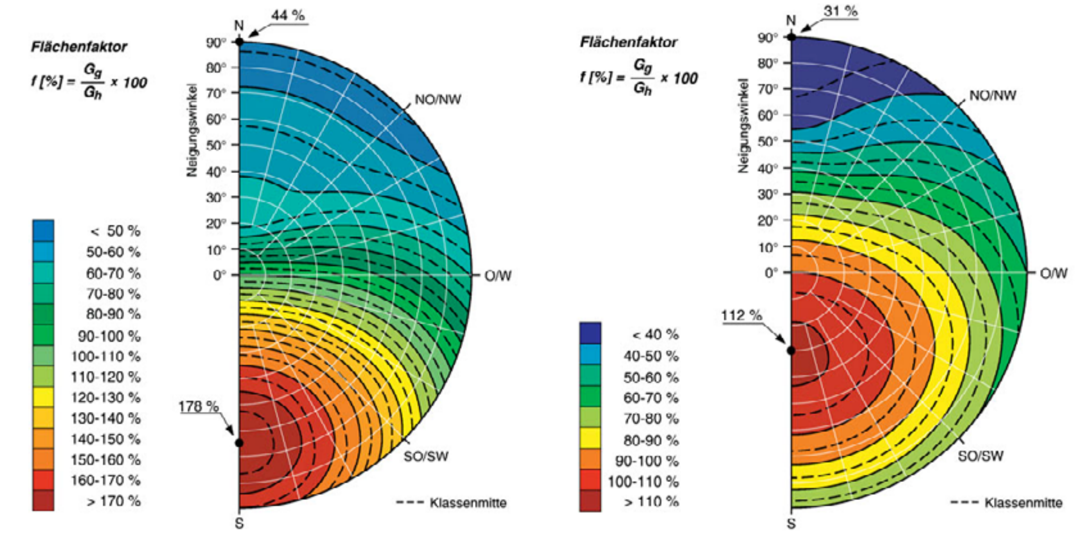
- Optimal orientation: An optimally orientated building for the use of solar energy is providing windows (passive use) and usable surfaces (active use) to the South.
- Avoidance of shading: The reduction of gains by solar use can cause considerably higher fuel demand (increase of final energy).

Referring to the orientation issue the importance of orientation to South can be clearly shown for both, passive and active use of solar energy.

Solar radiation is differing between regions, but it is also dependent on orientation and angle (roof slope) of surfaces exposed to the sun. The following figure shows examples (January and August) for different amounts of solar radiation to be expected for various orientations and angles (for the example of a German region). Even though the optimal angle in this exemplary region is 35° in average throughout the year[21] (JRC 2010) horizontal surfaces (as e.g. windows) are able to gain a considerable amount of solar radiation whereas northern orientation reduces the options for solar gains massively.

21 In Austria the average optimal angle throughout the year is 35° as well, depending on the location within Austria it ranges between 28° and 40° (JRC 2010, downoad 15.9.2010).

Figure 25: Solar radiation in dependence of orientation and angle of exposition in the months of January and August (example of Nordrheinwestfalen, Germany)

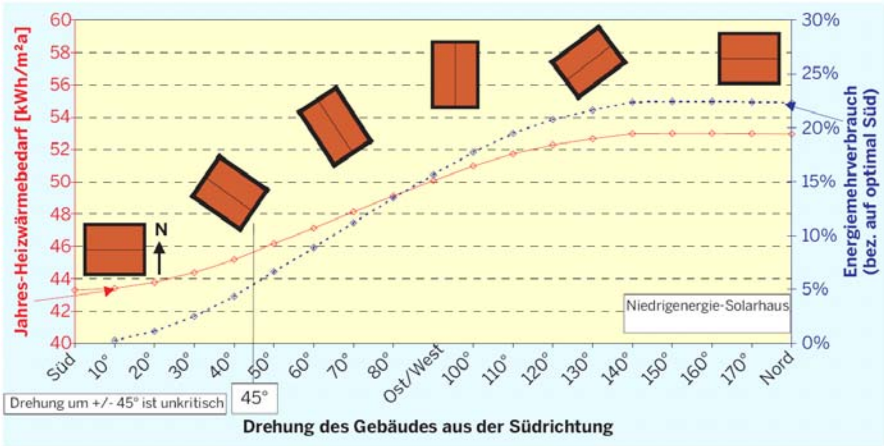


Source: Solaratlas Energieagentur Nordrheinwestfalen (download 8.4.2010)

Thus, the orientation of a building highly influences the amount of passive solar gains, which are able to substitute transmission losses to a certain extent (heat losses through the thermal envelop of the building). Overall, a benefit of heat energy due to energy gains against transmission losses can only be achieved in case of orientation to south (with a deviation of about +/- 30° in maximum, Sustainability Center Bremen 2009, Wirtschaftsministerium Baden-Würtemberg 2007).

The following figure presents the consequences of turning a building away from orientation to South. Whereas a deviation from south of up to 20° is not critical at all and a deviation of about 45° does influence the options for solar use only to an acceptable extent (need for about 5% more energy for heating), East/West orientation leads to a higher energy demand for heating of about 15% and an orientation towards North concludes in about 22% higher energy demand (according to calculation by computer simulation, EnergieAgentur.NRW 2008).

Figure 26: Annual heat demand of an exemplary building related to orientation



Note: Bulding with a share of windows of 70% in the South, effects of turning the building starting from South orientation (calculation by computer simulation)

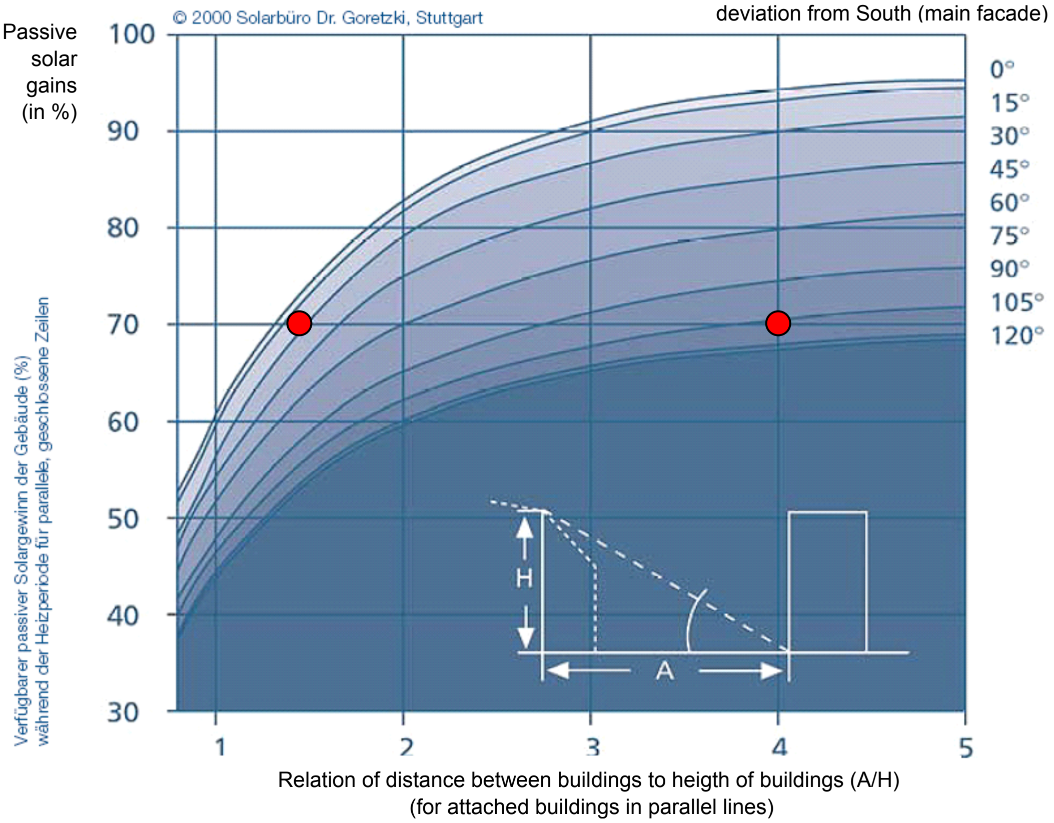
Source: EnergieAgentur.NRW 2008

Shading is another important issue to be considered in terms of solar gains. Figure 26 presents the possibility of passive solar gains (solar radiation to vertical surfaces) in dependency of deviation of south of the main facade together with the space between linear developments (for attached buildings in parallel lines) and accordant shading. A passive solar gain of about 70% i.e. can be achieved at the same time (see figure 27, red dots):

- by buildings constructed relatively close to another (with a distance-to-height ratio of about 1.4) but oriented nearly to South (deviation to South of about 15°) and
- by buildings with a South deviation of about 105° if there is a lot of space in-between (distance-to-height ratio of about 4).

Hence the figure points out the interdependency and importance of both parameters for the question of shading, namely south orientation and the space between the buildings (distance-to-height-ratio) (Goretzki 2000, Wirtschaftsministerium Baden-Würtemberg 2007). When reducing the distance-to-height ratio to a value below 2, the options for gaining passive solar energy are increasingly reduced.

Figure 27: Passive solar gains in buildings in dependence of deviation from South (main facade) and distance between buildings (attached buildings in parallel lines) in percent

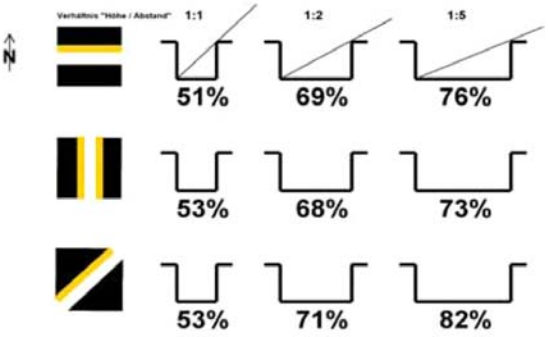


Source: Goretzki 2000, own translation

The same interdependency – but beyond one building (both sides of a street) – is shown in the following figure for exemplary orientations of streets (East-West E-W, North-South N-S and South-West to North-East SW-NE) and different distance-to-height ratios. Again, it can be shown, that orientation towards south and adequate space in-between buildings is decisive. Nonetheless, an optimised setting (in terms of total passive solar gains) considering all buildings along a street is not to be found in Southern orientation in any case.

In figure 28, the consequences of these different orientations are shown for the total street and for single buildings additionally, it points out a higher total solar energy gain for a building development along SW-NE streets. Whereas facades towards the street gain solar energy in case of N-S orientation of streets at both sides, this is not the case when streets are oriented E-W or SW-NE.

Figure 28: Solar radiation to facades in case of different distances between buildings



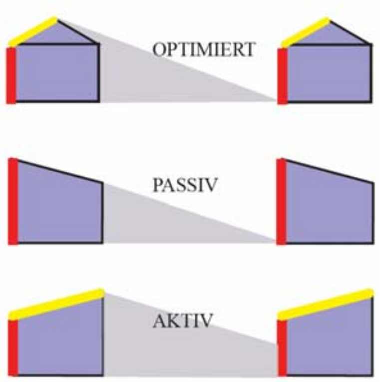
Source: Bundesamt für Energie (BFE) 2006, original source: Energy Research Group

The same interrelationship has to be taken into consideration in terms of active use of solar energy, namely energy production by solar thermal (heat) or photovoltaic installations (electricity). The amount of solar radiation to be gained at a specific location with a certain exposure is directly effecting the amount of produced heat respectively electricity.

Additionally to the use of roofs, also vertical surfaces can be used for active solar use (if sufficiently exposed to the sun, as e.g. stand alone high-rise buildings). Despite a lower yield of hot water in total, in terms of heat production by solar thermal installations this even has the advantage of comparatively higher yields in spring and autumn in which the hot water demand can be stated to be higher as well (if used for hot water plus heating purposes).

Nonetheless, in context with passive and active solar gains potential conflicting objectives have to be taken into account (Peseke, Roschek 2010).

Figure 29: Passive versus active solar use



Optimised for passiv and activ solar use

Optimum for passive solar use

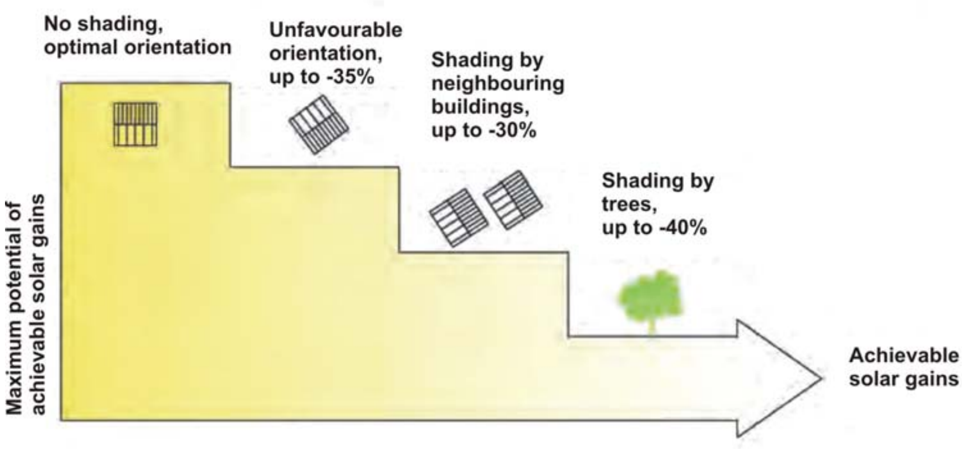
Optimum for active solar use

Source: Peseke, Roschek 2010

For active solar use in buildings primarily roof surface is used for energy production, thus it is important to expose roof areas to the sun. In case of passive solar use it is decisive to expose windows and walls to the sun, which can interfere with active use

of solar energy due to shading. Thus an optimisation between passive and active solar use should be taken into consideration (fig. 29).
Shading can be caused by short distances between buildings (in relation to building heights), but also by trees and even by topography (locations with shading by topography, mainly north slopes, should be avoided generally if possible).
As shown in the following figure, there are similar shares of decrease of potential solar gains between the issues of orientation of the building, shading by buildings and shading by trees.

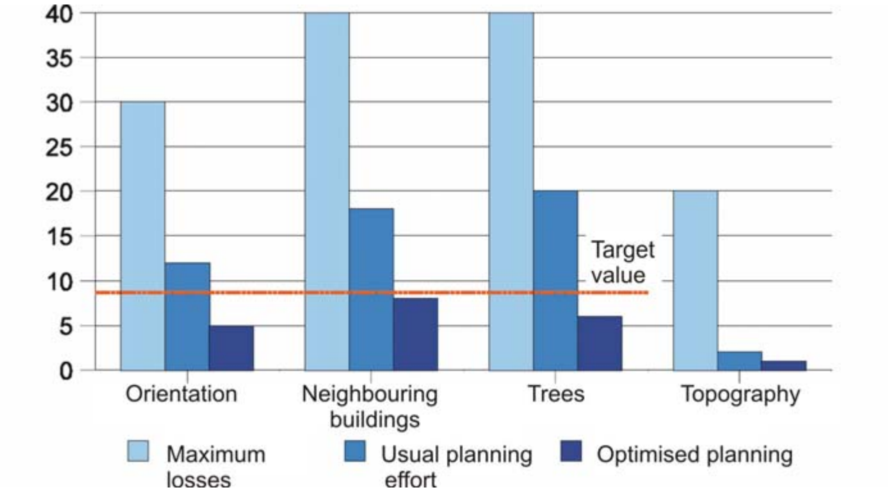
Figure 30: Aspects of urban planning affecting achievable solar gains



Source: Stadt Essen, Amt für Stadtplanung und Raumordnung 2009, own translation

From a maximum of 100% of solar gains, between 95% and 35% of solar energy can be used in practice, thus possible losses of solar energy range between only 5% but up to 65%. Figure 31 points out the possibilities to avoid solar losses by planning. Clearly there is a large range between solar energy, which could be gained, and losses due to ‘usual planning’ and optimised planning.

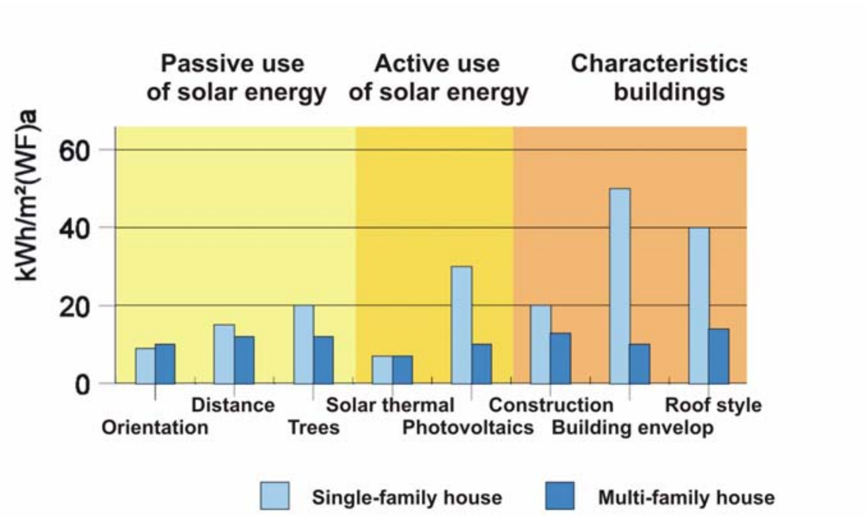
Figure 31: Losses of solar energy due to urban design (in %)



Source: Goretzki 2008, own translation

There are a number of characteristics and parameters to be optimised in order to maximise the total amount of solar energy to be gained within an area. The following figure presents the influence of selected parameters on active and passive solar use for single-family and multi-family buildings. This comparison clearly shows that the amount of solar energy (per m^2 living space) to be gained in single family house areas is higher than in more densely developed quarters, mainly caused by the ratio of living space to roof surface (active solar use) and less options for the avoidance of shading in multi-family house areas.

Figure 32: Energy gains due to optimisation of single buildings



Note: Energy gains in kWh / m^2 (WF ... living space) per year

Source: Goretzki 2008, own translation

As stated by Goretzki (2008) energy aware planning should minimise solar losses, specified as losses of solar energy below 20% in total (including orientation and shading by buildings and trees).
For new developments of a certain size (development areas), an optimisation of solar gains including a preferably fair distribution of passive solar energy gains between buildings (also determining available sunlight in flats which is important for personal comfort and quality of life) should be taken into consideration. This can only be done by detailed solar analysis (see further chapter 2.4.4).

General guiding principles referring to solar orientation

Following main principles can be formulated based on available literature:

- ***Maximising passive (heat) energy gains***
  - Orientation to south
  - Avoidance of sun shading
- ***Active use of decentral renewable energy***
  - Considering options for active solar use

2.3.3 Consideration of Wind Regime

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

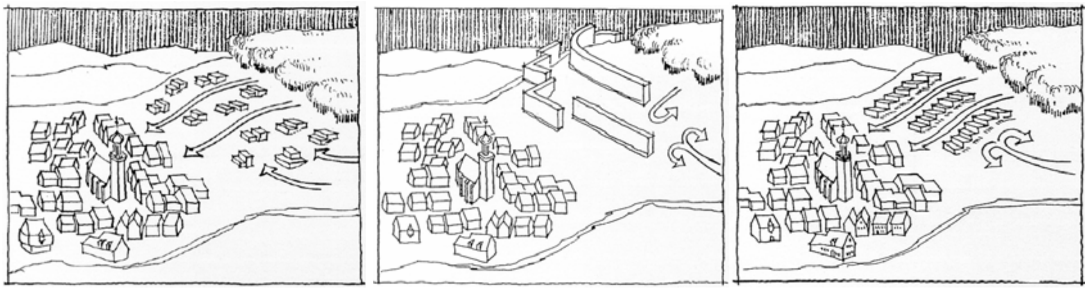
The consideration of wind regime refers to two conflicting topics, namely

- the avoidance of exposition of buildings to the wind (minimising heat demand), in order to avoid heat losses due to higher ventilation and transmission losses in buildings, and
- the mitigation of heat island effects by aeration and urban ventilation effects (minimising cooling demand), leading to lower energy demand for cooling (compared to heated up quarters without ventilation effects).

Both topics are little analysed in terms of overall energy losses in settlements or cities, thus the following description has to stay qualitative, even though especially heat islands are stated to become more important in future.
As stated above (2.3.1 Urban density) compact urban settlements, which are protected from wind exposition together with urban heat island effects, can lead to a reduction of heat demand of up to -15% (EnergieAgentur.NRW 2008).

In relation to wind exposition, certain constellations can be stated to show specific effects on aerial situations in general. The following figure presents selected aerial situations such as a permeable hillside development allowing for ventilation of downhill urban structures, but with hillside located buildings being exposed to wind (1), linear development parallel to the hillside with a shielding effect and no ventilation of downhill urban structures (2) and hillside development with 'latch-plate' effect, providing a potential to ventilate urban structures nearly without being exposed to wind at the hillside (3). In the German Climate Booklet for Urban Development it is stated, that hillside developments – if not avoidable at all – in general should not exceed a certain height and offer large open green space in-between buildings, in order to provide good conditions for ventilation with the natural downstream of cool air (Wirtschaftsministerium Baden-Würtemberg/ Amt für Umweltschutz Stuttgart 2008).

Figure 33: Aerial situations: Permeable hillside development - linear development parallel to the hillside - hillside development with "latch-plate" effect



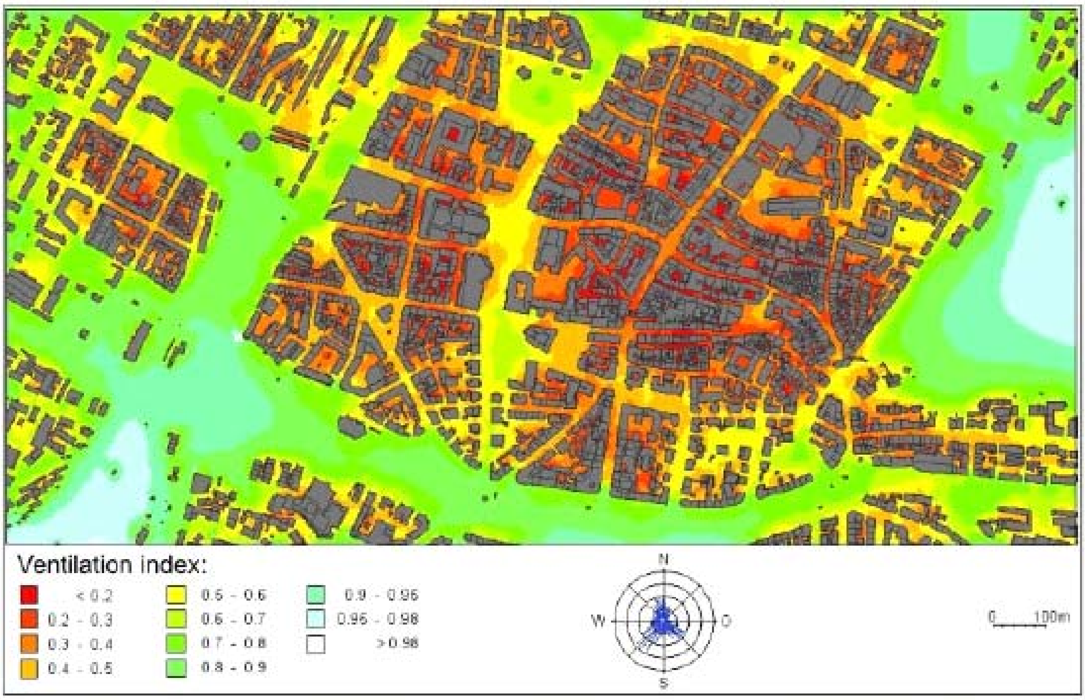
Source: Wirtschaftsministerium Baden-Würtemberg/ Amt für Umweltschutz Stuttgart (2008)

Whereas ventilation of urban structures was a topic mainly of air quality and heating demand in the past, it has recently gained importance in the context of urban heat island research (and resulting in cooling demand).

Urban heat islands are an increasingly analysed topic in science and research even in context with urban planning. Its effect on energy demand due to the need for cooling of buildings is stated to become more important in future. Today these interrelationships are of importance mainly in areas of hot climate, in Austria the issue of cooling is still of lower importance.

In general, urban heat island effects can be lessened by ventilation with cool air. The following figure presents the aeration potential of the city centre of Freiburg in the annual average. Different conditions within the urban structure can be easily extracted on the basis of such ventilation maps. The interrelation between densely built up urban structures and low ventilation is clearly presented as well as higher ventilation in more open areas. Depending on the prevailing wind direction, aisles within the built up area (in wind direction) – as i.e. often determined by rivers - may help to ventilate urban structures to a higher extent.

Figure 34: Aeration potential of the city centre of Freiburg in the annual average



Source: Wirtschaftsministerium Baden-Würtemberg/ Amt für Umweltschutz Stuttgart (2008), original source: (RÖCKLE & RICHTER, 2003)

The consideration of the aerial situation at an overall as well as at a local scale is necessary in order to estimate effects of wind exposure and urban heat island effects. The importance of those two widely contradicting issues is dependent on climatic factors as well as on the specific local situation.

General guiding principles referring to the wind regime

Following main principles can be formulated based on available literature:

- ***Minimising losses of (heat) energy***
    - Consideration of aerial situations (heat losses versus lessen heat island effects)

2.3.4 Connectivity and design of streets and pathways

Minimising losses of (heat) energy	Maximising passive (heat) energy gains	Active use of decentral renewable energy	Efficiency due to energy services by common supply	Minimising VMT, environmentally friendly mobility

Connectivity, attractive design and security have to be seen as important additional asset especially to the prerequisites of locational and functional mix questions as well as urban densities. As defined by Cervero and Kockelman (1996) there are three 'Ds' to be taken into consideration – density, diversity (land use mix) and design – which are affecting the travel demand moderately in general. In the study 'design' is related to:

- Street characteristics (grid pattern and connectivity, speed limits, street widths, etc);
- Pedestrian and cycling provisions (sidewalks, planting stripes and trees, lighting, cycling lanes, traffic lights, block length and sidewalk width, slope, etc.);
- Pedestrian friendly design (e.g. no setbacks, parking conditions on-street/off street);

Ewing et.al. (2007) state that the number of 'D' variables has to be enlarged by adding destination accessibility (number of jobs or other attractions within a given travel time) and distance to public transport.

Furthermore it has to be mentioned, that Cervero and Kockelman point out that – if transportation benefits shall be accrued - it is necessary to consider all (three) aspects to a certain extent. Additionally, it has been shown, that neighbourhood characteristics are generally affecting modal choice for non-work trips to a higher extent than trips for commuting (Cervero and Kockelman 1996).

Thus, connectivity and design of streets and pathways are two aspects of local design questions, which are important for appropriate construction of settlements for environmental friendly modes of transport. This refers to walking and cycling as well as to the use of public transport, which is usually accompanied with a short walk or ride on the bike additionally.

The length of blocks respectively the density of crossings (street accessibility or connectivity) is an important criteria determining the possibility of direct connections and trip lengths in order to avoid detours. This is especially important for attractive-ness of walking and cycling. As example for unfavourable design, the following figure shows detours, which are determined by lacking connectivity in a housing area. Due to the outline of the streets and lacking pathways between the plots (red dotted line), neighbours have to accept quite far detours even by walking or cycling (black line). Due to such street layout the probability of driving by car increases (e.g. Litman 2010).

Handy (2005b, citing Ewing and Cervero 2002) also points out a correlation between local design (defined as sidewalk completeness, route directness and street network density) and transport. Calculated elasticity between those issues show a statistical significant, but not very high correlation of about -0.05 on vehicle trips and of about -0.03 on VMT. Thus an 'increase' of about 10% of the defined design elements is expected to cause about 0.3 % less VMT or 0.5% less vehicle trips.

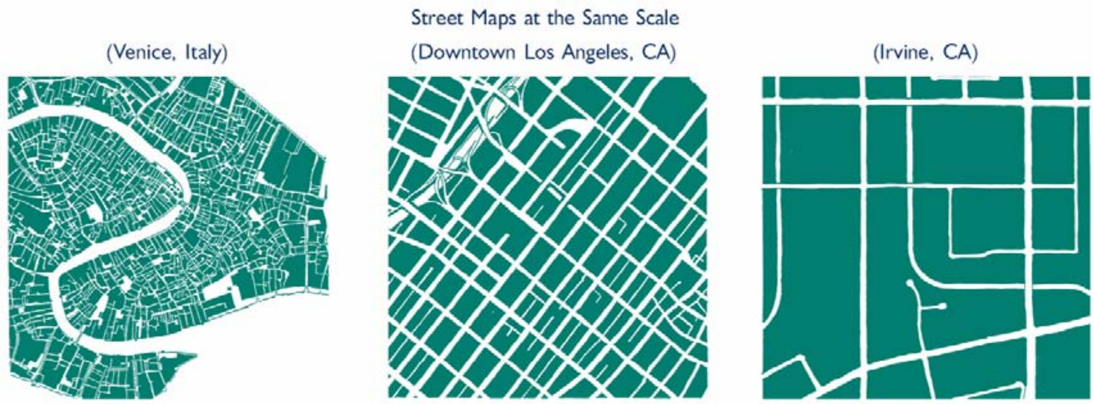
Figure 35: Unfavourable connectivity of streets for walking and cycling (example)

Source: http://www.herold.at/routenplaner/

As pointed out by ITE (2010) an effective network planning is necessary for walkable areas. The following comparison of urban areas in Venice, Los Angeles and Irvine clearly reveals the spread of connectivity levels as well as the effect of connectivity or density of intersections on the walkability within an urban quarter. The three examples show a decrease of intersections per square mile of factor 10 each.

Whereas Venice can be stated as highly walkable, the urban area shown for Los Angeles is far less walkable (with a density of intersections per square mile of only 150 compared to Venice with 1,500). A design, which is not favourable for walking at all, is presented in the third picture (urban area in Irvine with only 15 intersections per square mile).

Figure 36: Density of intersections and walkability of urban areas



Source: Ewing 1999 , original source: A.B. Jacobs, 1993,

In a recent meta study carried out by Ewing and Cervero (2010), comparatively high elasticity (average weighted values over the analysed empirical studies) on walking and public transport use have been presented by changing connectivity qualities. According to those results, street intersection density is showing elasticity of 0.39 on walking and of 0.23 on the use of public transport.

Additionally to connectivity (also due to additional walking and cycling paths as e.g. by links through blocks of houses in urban structures) the design of pathways and the consideration of traffic security is important. Attractive design supports comfortable walking and cycling from a subjective point of view as well as objectively. Litman (2010) comes to the conclusion, that the improvement of walking and cycling conditions tends to increase non-motorised travel and thus reduces car traffic for the comparison of persons living in walkable and car dependent communities. Referring to walking and cycling conditions, he points out about 2-4 times higher number of walking trips and a reduction of VMT of about 5-15% for persons living in walkable communities. In terms of scale, design and management of streets, he further states that multi-modal streets (including traffic calming and favourable design for walking and cycling) increase the use of alternative modes (walking, cycling) of transport and reduce vehicle travel.

General guiding principles referring to connectivity and design of streets and pathways

Following main principles can be formulated based on available literature:

- ***Minimising VMT by environmentally friendly mobility***
  - Avoiding detours for walking and cycling
  - Attractive design and high security

2.4 Interrelation of spatial planning measures and energy demand – an overview

2.4.1 Integrated analysis and summary on findings

Based on the systematic description in terms of the interrelation of specific measures of spatial planning on divers energy issues in reality it is necessary to consider the whole system of possible effects as well as their potential together in each specific situation.

Following the general guiding principles for energy aware spatial planning, the overall picture on recommendations leads to a number of complementary principles and a few contradictions, which should be considered and have to be balanced from case to case.

Table 5 presents an overview on guiding principles from the literature review (chapters 2.2 and 2.3), showing the interrelation between measures of spatial planning and energy issues as well as different aspects of these interrelationships and their importance.

Table 5: Overview on general guiding principles

	Topography	Location, municipal shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Minimising (heat) energy losses	consideration of wind regimes attention on hilltops and basins advantages by wind shading avoidance of north slopes			sufficient green space use of shading	consideration of building types		consideration of aerial situations	
Maximising (passive heat) energy gains	avoidance of sun shading			considering passive solar use		orientation to South avoidance of sun shading		
Use of renewable energy sources	options for active solar use			options for active solar use	options for use of near surface geothermal energy	options for active solar use		

.... guideline

.... less analysed respectively mainly qualitatively based guideline

Overview on general guiding principles (continuation table 5)

	Topography	Location, municipal shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Common, efficient energy service provision *Built environment*			consideration of location of heat sources and heat consumers		options for district heating systems densification at certain locations (heat sources)			
Mobility		development near of high level PT	mixed functions for higher PT demand		options for public transport			
Minimising vehicle miles travelled (VMT), environmentally friendly mobility	avoidance of steep slopes	location in short distances to the centre avoidance of dispersed settlements compact shape	mixed functions / area with local supply	sufficient green urban space	options for local supply			avoiding detours for walking and cycling attractive design and security

.... guideline

.... less analysed respectively mainly qualitatively based guideline

The potential impact of following these guidelines is depending on various framework conditions. Nevertheless, the following table summarizes findings from available literature in terms of the potential quantitative impact of single measures in the range of spatial planning.

Although it is clear, that

- the respective quantitative estimation is presenting rather a maximum, showing the range up to which a potential for possible impacts is given,
- those estimates relate to different items (e.g. energy demand for heating, active or passive solar gains, VMT, vehicle trips, CO_2, etc.),
- there is quite a high range for some of the estimations referring to the effect on energy demand (also due to different underlying assumptions), and
- these quantitative specifications are taken from different literature (empirical studies and calculations) and are not harmonised and thus can only be compared carefully with each (even if the same item is specified).

Nonetheless the overview is stated to present valuable information on importance and effects of single interrelationships (as far as data is available).

In some cases, there are interrelationships stated for which no quantitative estimation is available (especially referring to effects of green open spaces). Partly this is due to the fact that some aspects can hardly be compared directly. The effect of municipal shape is affecting energy use together with a wide range of other factors (as e.g. land use mix, location of industry and services, size and centrality of the municipality). Municipalities are showing very specific conditions and frameworks each. Thus, even if detailed data on energy demand is available, it is difficult to deduce effects from municipal shape and separate them from other influencing factors on energy demand.

Table 6: Dimension of energy savings respectively additional energy demand by land use planning (based on literature review)

	Minimising (heat) energy losses	Maximising (passive heat) energy gains	Use of renewable energy sources	Common, efficient energy service provision (district heating, public transport)	Minimising vehicle miles travelled (VMT), environmentally friendly mobility
Topography	energy demand (heating): (windy) hilltops, estimation between +3% [2] up to + 10%[1] (up to +100% [7]) basins (*cold air flowing basins*), up to +20%[1]; wind shading (due to topography), up to -50%[7]	energy demand (heating): south slope: up to -15%, north slope: up to +15% [1]	*impact on options for solar energy yield up to –100%* *(relating to exposition to south, exclusive use of scattered radiation is not considered as realistic)*		-
Location, municipal shape				public transport for commuting: 30-60% in centred locations vs. 5-15% in dispersed loc. [5] PT use elasticity of 0.29 ref. to distance to nearest PT stop [8]	VMT elasticity: -0.22 referring to distance to downtown [8]
Functional mix of uses				PT elasticity: 0.12 referring to land use mix [8]	VMT elasticity: land use mix/diversity -0.05 [4] up to -0.09[8] walking elastices[8]: land use mix: 0.15, job-housing balance: 0.19, distance to store: 0.25 good mix neighbourhoods have 5-15% less VMT [5]
Green spaces	-	-	-		-

Sources:

[1] ... EnergieAgentur.NRW 2008
[2] ... Peseke/Roschek 2010
[3] ... Goretzki 1999
[4] ... Ewing/Cervero 2002 (cited in Handy 2005b)
[5] ... Litmann 2010
[6] ... Ewing et.al. 2007
[7] ... Wende et.al. 2009
[8] ... Ewing and Cervero 2010
[9] ... GEMIS 4.6 2010
[10] ... Wirtschaftskammer Österreich, 2007, Original data source: Jungmeier, et al. (1996)

Table 7: Dimension of energy savings respectively additional energy demand by local construction plans (based on literature review)

	Minimising (heat) energy losses	Maximising (passive heat) energy gains	Use of renewable energy sources	Common, efficient energy service provision (district heating, public transport)	Minimising vehicle miles travelled (VMT), environmentally friendly mobility
Urban density	MFH versus SFH, at least -30% energy demand for heating[10] (buildings of the 90s) heat islands, up to -15% energy demand for heating (winter)[1]		*additional energy provision: dependent on type of energy source and capacity of energy production*	DH (gas driven) versus gas heating, up to -40% CO_2 [2] DH (wood based) versus gas heating up to about -80% CO2 and fossil PE [9] VMT elasticity: 0.07 referring to pop. density [8]	VMT elasticity: -0.04[8] respectively -0.05[4] up to -0.1 to -0.3 [5], higher density probability of 0.3 PT commuting - low density only probability of 0.1[6]
Solar orientation		non shaded versus strongly shaded buildings, passive solar use up to -20% (heat energy) [2] loss of passive solar gains deviation of south orientation of windows, up to +15% (east/west) +20% (north) [1] + 30% (least favourable orientation) [2] and + 75% (orientation plus shading) [3]	active solar use, optimally oriented roof, up to – 10-15% in comparison with not favourable oriented roof [2]		
Wind regime	urban compact settlements, up to -20% (heat energy) [2]				
Connectivity and street design					elasticity in terms of street design -0.03 ref. to VMT and -0.05 ref. to vehicle trips[4], in terms of connectivity: 0.39 ref. to walking[8] walkable communities 2-4 times more walking, 5-15% less VMT [5]

Sources: see previous page

Table 6 is presenting final conclusions about important interrelationships between measures of spatial planning (topics) and energy issues as a summary from the overview on guiding principles for spatial planning (table 5) and the dimension of energy savings by land use planning to be found in available literature (shown in table 7).

It clearly shows the complexity of different relationships and interdependencies between measures of spatial planning and energy issues.

Energy issues affect the spheres of living – namely the built environment and mobility – in a different way (bottom of the following table). Whereas the energy issues 'minimising energy losses', 'maximising energy gains' and the 'use of renewable energy' are influencing the energy demand of the built environment in first place, 'minimising VMT' and 'environmental friendly modes of transport' are affecting the energy demand for mobility. Only one of the described energy issues is affecting both spheres of living, since the 'common provision of energy services' is referring to district heating services (built environment) as well as to public transport services (mobility).

Finally, referring to the effects of spatial planning measures on aspects of energy demand, there are not only single effects to be stated, but also synergies (by optimisation) and trade offs (by 'combating' principles, indicated also by the flash symbol in table 8) between different measures of spatial planning.

The second table (9) shows the interrelation of spatial planning measures to each other, it highlights which measures support each other in their effects and which measures might show contradictory trends.

Table 8: Scales and relevant topics of spatial planning and contribution to/ interdependence with energy issues

Scales and topics of spatial planning	Energy issues	Minimising (heat) energy losses	Maximising (passive heat) energy gains	Use of renewable energy sources	Common, efficient energy service provision (district heating, public transport)	Minimising vehicle miles travelled (VMT), environmentally friendly mobility
Land use planning	Topography	X	X	X		(x) ↯
	Location, municipal shape				X	X
	Functional mix of uses				X	X
	Green spaces	(x)	(x)	(x)		X
Local construction plans	Urban density	X	↯	(x) ↯	X	X
	Solar orientation		X	X		
	Wind regime	X ↯				
	Connectivity, street design					X
Affecting different spheres of living						
Built environm.						
Mobility						

X .... important interrelation, considerable effects on energy demand

(x) .... of relevance but not as important, less analysed respectively qualitative description

↯ .... interference with objectives in terms of energy issues possible (counteracting effects)

Table 9: Related and interfering topics of spatial planning (referring to energy issues)

		Land use planning				Local construction plans			
		Topo-graphy consider-ation	Location, municipal shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connect-ivity and street design
Land use planning	Topography consideration		X		X		X	X	
	Location, municipal shape			+		+			
	Functional mix of uses					+			
	Green spaces					-	+	+	+
Local constr. plans	Urban density						-	+ -	
	Solar orientation								
	Wind regime								
	Connectivity								

x ... Related topics, one topic may influence another topic in terms of characteristics and options

\+ ... Synergies between topics possible (important for energy issues)

\- ... Trade offs between topics likely (important for energy issues)

Conclusions

The overview on quantitative estimates of potential effects (tables 6 and 7) shows that there is not one single measure, which is most important in terms of reduction of the overall energy demand. It is a number of various measures, which can contribute to energy efficiency and mitigation if integrated implementation takes place. The effect of single measures can vary widely, every spatial planning action has to be analysed and it has to be decided upon from case to case.

Nevertheless in total a relatively high contribution to a reduction of CO_2 (and other GHG emissions) can be achieved if energy issues are taken into consideration seriously.

Concluding from the overview on scales and relevant topics of spatial planning (table 8) it can be stated, that both scales of spatial planning – land use planning and local construction plans – can have a considerable impact on energy demand in the sphere of the built environment as well as in the sphere of mobility.

Whereas land use planning forms the background for energy aware planning, local construction plans can be seen as an instrument of ‘fine tuning’ at specific locations.

Thus land use planning is the scale of planning which has to focus on the municipality as an entity, an assessment of land use planning has to take into account the urban context – the overall situation – as well as specific circumstances and conditions within the municipality. Principal decisions on the location of measures should be compared against optional alternatives. Local construction plans in contrast are usually focussing on a specific area, surrounding conditions are less important in this (later) phase of planning.

Urban density is important in terms of both, built environment as well as mobility. The grade of urban density itself influences a number of interrelations (especially in the context of common energy services referring to district heating systems as well as to public transport supply). Additionally its interference with different energy issues (solar use, use of renewables in general, heat island effect) has to be taken into account. Overall it is a highly sensitive topic (also in terms of acceptance of certain density levels in varying urban and rural structures), which has to be balanced case by case carefully, depending on the framework and locational conditions.

In addition to the synergies to be benefited, some counteracting effects have to be taken into consideration (flash symbol in table 8, table 9).

This is especially important for following relations:

- Topography – minimising vehicle miles travelled (VMT): The guiding principle of avoiding settlements at North slopes might interfere with the objective to strive for short distances and a compact municipal shape. In addition to the total estimated energy demand also quality of living has to be taken into consideration in such cases. The decision on building up such areas (for housing or other purposes) has to be taken carefully.
- Urban density – maximising energy gains: High urban densities may especially interfere with the use of passive solar energy due to higher rates of mutual shading by buildings. Thus this interrelationship additionally influences the possibilities of another energy issue, namely solar orientation.
- Urban density – use of renewable energy sources: Due to the same interdependency high urban densities may also interfere with the use of active solar energy. In addition high urban density minders the possibility of near surface geothermal use (heat pumps) due to less useable open space (e.g. in contrast to private gardens in case of single family homes).
- Wind regime – minimising energy losses: In context with the wind regime their are two effects of importance which are interfering to each other: On the one hand heat losses have to be stated due to wind exposition in the heating season, which can be avoided by compact densely built structures (1), but on the other hand there is also the possibility for less need for cooling due to wind exposition in the summer season (lessen heat island effects) (2). Whereas in city centres the effect of heat islands in the summer season will be probably of higher importance, smaller villages and outskirts (with lower densities of built structures and a higher share of green open space) will set the focus on avoidance of wind exposition to minimise energy losses in the heating season. Priorities will be set also due to local climatic and microclimatic framework conditions.

Referring to the influence on the two considered spheres of living it seems obvious, that land use planning is setting important framework conditions for the built environment, while it is even more important for mobility issues.

In contrast, besides urban density, the planning scale of local construction plans is less important for the sphere of mobility, but it can contribute a lot in terms of the energy demand caused by characteristics of the built environment.

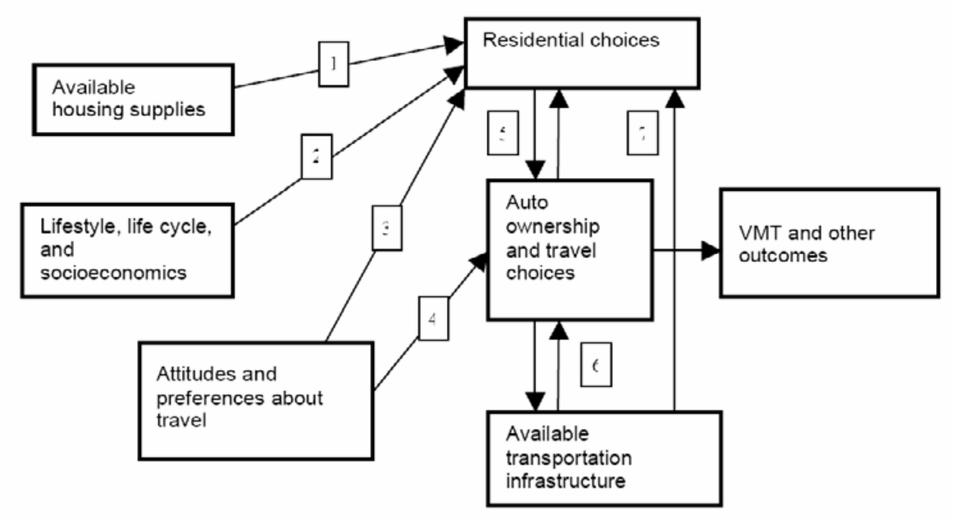
Based on the findings in terms of most important synergies and trade offs the following main conclusions may be derived:

- Topography is an important framework condition; consideration of topography has to be seen as a prerequisite for energy aware spatial planning.
- By land use planning mainly synergies can be achieved in combination with measures of local construction plans in a later phase of planning. Considerable improvements to be achieved by integrated implementation of the principles of energy aware spatial planning.
- These synergies are most important in the sphere of mobility, where an integrated approach can lead to considerable success (best results can be achieved by common concepts for location and municipal shape, functional mix and urban density).
- From the perspective of energy aware planning, energy aware conceptualisation of local construction plans is more difficult due to a number of trade offs between single aspects (e.g. wind regime: heat islands in summer, potentially causing cooling demand, versus higher heat demand in winter; or solar gains due to avoidance of shading versus efficiency due to density, etc.). In case of single locations it is valuable to follow the general principles as described above. For urban development projects of a certain size, it is recommended to use supporting calculation models in order to achieve an optimisation by balancing synergies and trade-offs.
- Urban density is a key question both, in terms of importance for a number of aspects of energy demand as well as for balancing trade-offs. It has to be taken into consideration especially; decisions should be based on careful analysis of the local situation, interdependencies and overall objectives for future development.

2.4.2 Excursus on travel behaviour, socio-economic factors and the built environment

Transport decisions are not only based on the location of living but are influenced also by a number of other factors as shown below. Thus, to explain the effects of built environment characteristics on mobility issues (i.e. modal choice, trip length and trip frequency) in empirical studies, it is necessary to separate the effect of socio-economic factors from those of built environment characteristics. The following figure presents mechanisms of attitudes, preferences and local conditions, which may affect travel choices and VMT.

Figure 37: Mechanisms affecting travel choices and VMT



Source: Ewing et.al. 2007

Susan Handy refers in her evaluation of available empirical analyses to a study done by Ewing and Cervero (2001, cited in Handy 2005b). In this study important relations for the explanation of travel behaviour were formulated in terms of the relative importance of characteristics of the built environment and socio-economic characteristics (income, education, etc.). According to these findings in general it can be stated, that the built environment as well as socio-economic characteristics show effects on travel behaviour, but to a differing extent:

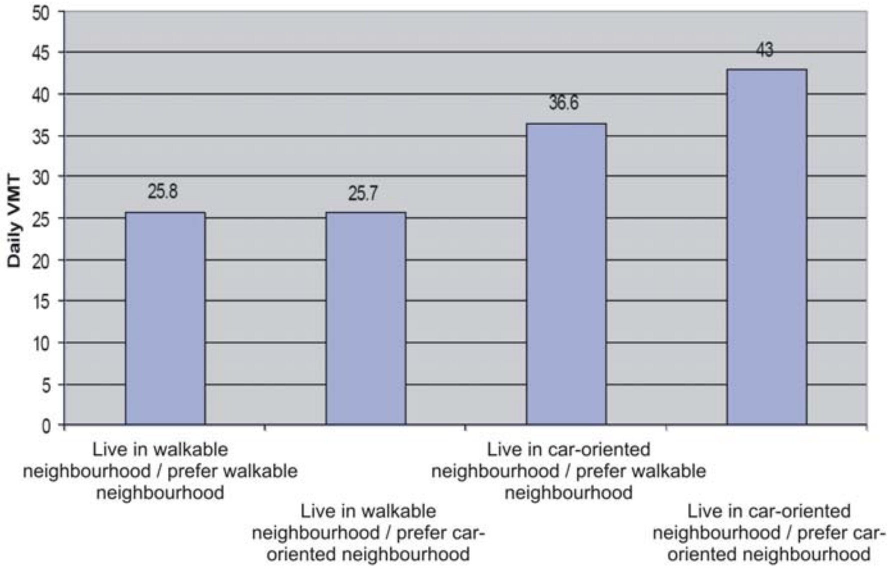
- Characteristics of built environment influence more significantly the issue of trip lengths and generally the issue of vehicle miles travelled (as an outcome of trip length, frequencies and modal split),
- whereas socio-economic parameters seem to be more important for trip frequencies and to a lower extent also for modal choices.

Nevertheless, there are a number of findings, concluding in a considerable correlation between specific characteristics of the built environment and mobility related to those areas, which will be presented in the chapter at hand.

In addition there is a general scientific discussion on the question of determinism versus 'self selection' (Ewing et.al., 2007). On the one hand a clear correlation between characteristics of the built environment and modal split (especially the use of private car respectively the vehicle miles travelled) has been substantiated by numerous scientific studies. On the other hand, the causality of this relation is questioned, as there are critics pointing out the possibility of 'self-selection'. This is referring to the possibility, that it is not the character of the built environment, which determines the behaviour of people, but that certain people choose neighbourhoods for living by certain criteria. Thus i.e. people who want to use public transport choose neighbourhoods providing access to high-level public transport (rather than others). This ‘self-selection’ would then again lead to a clear correlation of neighbourhood characteristics and the use of public transport, even if due to another cause.

Ewing et.al. (2007) present an in depth survey on 8,000 households (Atlanta), in which daily VMT was asked together with the preferences for neighbourhood characteristics. In addition, real neighbourhood characteristics were noted (following figure).

Figure 38: VMT by neighbourhood type and residential preference



Source: Ewing et.al. 2007, original source: Frank et.al. (forthcoming in 2007)

It has been shown, that there is also a substantial difference inbetween the group of people with preference for car-oriented neighbourhoods. Those living in walkable neighbourhoods drive less than those living in a car-oriented neighbourhood (VMT about -40%). Thus according to this study neighbourhood characteristics support walking even if preferences would suggest another behaviour.

Also another recent study (Xinyu et.al. 2008), which is based on a meta analysis of 38 empirical studies, finds a statistically significant influence of built environment characteristics remaining even after accounting for self-selection.

Finally, even if self-selection were the fact (and people living in those neighbourhoods are mainly those who choose especially such neighbourhoods) this would only strengthen the assumption of a higher demand but limited supply with those neighbourhoods. It does not principally disprove the hypothesis that also people not searching for specific neighbourhoods would use an attractive supply with public transport and comfortable walking and cycling paths to a higher extent (if accessible).

Nonetheless, neighbourhood characteristics as e.g. mixed functions and minimum densities allowing for local supply and public transport as well as attractive design for walking and cycling provide with the chance for not being dependent on car transport. This is stated to be important from a mitigation point of view as well as from a social point of view, especially in context with further rising energy costs and related danger of energy poverty, which has to be expected in the course of a development towards a 'post-fossil' future in a mid to long term perspective (BMVBS/BBSR 2009b).

2.4.3 Excursus on urban density – a challenge for setting thresholds and formulating general recommendations

As stated above, urban density is a key question for the transformation of our built environment into more energy efficient structures. In addition to varying definitions for density (dependent on the issue of calculation, e.g. population, floor space, open space, etc, see further chapter 2.3.1) it is important to define the delimitation of the analysed interdependencies carefully and thus to select the systems boundaries for the analysis.

These densities cannot be defined in absolute terms, there has to be accepted a range of appropriate densities, which are (respectively may be):

- different between urban agglomerations and large cities and rural areas (e.g. due to varying acceptance of high rise buildings or other densely built urban structures and a renunciation of private gardens);
- different from country to country (e.g. due to varying traditions);

In addition in existing (built up) areas, such densities are changing over time. Different developments (also within one municipality) may take place due to e.g.:

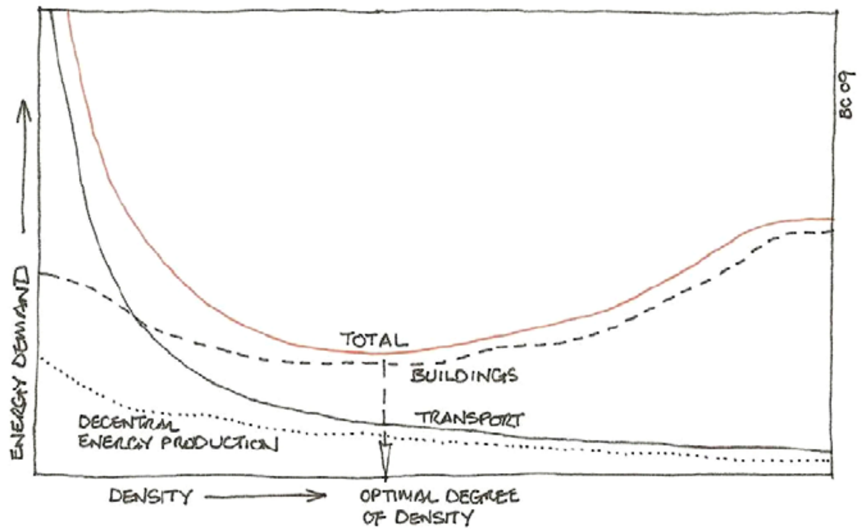
- present trends of transformation of the built environment (e.g. decrease of specific energy demand for space heating)
- a change of needs and behaviour (as e.g. increase of floor space per capita due to economic wealth)
- general population development in different areas (ageing population, decrease of average persons per household, which is determining floor space per capita as well).

Thus it is not possible to define universally valid 'right' or 'ideal' densities but it is possible to search for a range of optimised or 'appropriate densities' (Westphal

2008) which are limited by quantitative targets and qualitative objectives (minimum and maximum limits due to specific analysed interrelations).

As stated above, from the point of view of energy demand, a positive correlation between density and energy efficiency can be argued in general. Nevertheless, this positive correlation can turn into a reverse relation after exceeding a certain maximum limit of density. In principle such effects are known, whereas it is difficult to define those limits quantitatively in reality. The following sketch (fig.39) describes this principal relation between increasing density and energy demand for buildings and mobility.

Figure 39: Principle sketch to identify the optimal degree of density based on energy demand and decentral energy production



Source: Cody 2009

Whereas energy demand for transport is stated to decrease steadily with the increase of population (and job) density there is a change of energy demand in terms of energy demand of buildings e.g. due to the additional energy demand for technical appliances within high rise buildings (e.g. elevators, electricity demand due to building automation). Support for this for now rather principal approach of the relation between density and energy demand (Cody 2009) is given by Rickwood et.al. (2008) in the empirical analysis of actual energy data on operational energy per dwelling, showing highest energy demand for detached buildings as well as for high rise buildings (with more than 9 storeys), whereas semi-detached, low and medium rise buildings show considerably lower energy demand.

Suggestion for defining an ‘appropriate density range’ for a specific urban context

Concluding this important but sensible topic, the following listing of limits is not non-exhaustive, but it shall indicate aspects which shall be taken into consideration in the course of defining an ‘optimal range’ of densities for a specific area. Such limits are not only based on pure energy aspects - energy efficiency and mitigation respectively the objective of reducing the energy demand (referring to final energy as well as to primary energy) - but have to consider also other aspects as economic and social issues, which again have an effect on energy demand (as shown above, e.g. public and shopping infrastructure/mixed use with effect on transport modes and VMT, etc.).

As stated above, to estimate an appropriate density for a specific area, systems boundaries should comprise not only on the analysed area or the analysed project, but at least a wider, surrounding area and possibly consider the situation in the municipality or the urban quarter (in case of a large city) in addition.

Referring to minimum limits the following aspects should be included in the analysis:

- Energy demand for space heating due to building type (single family houses vs. terraced houses vs. multi-family houses) in general;
- Heat densities due to building types and standards (thermal envelop) in context with district heating systems;
- Potential demand for public transport due to population and job density;
- Potential demand for provision of local supply (neighbourhood shopping, dependent on micro-economic limits) and public infrastructure (kindergarten, schools, etc.);

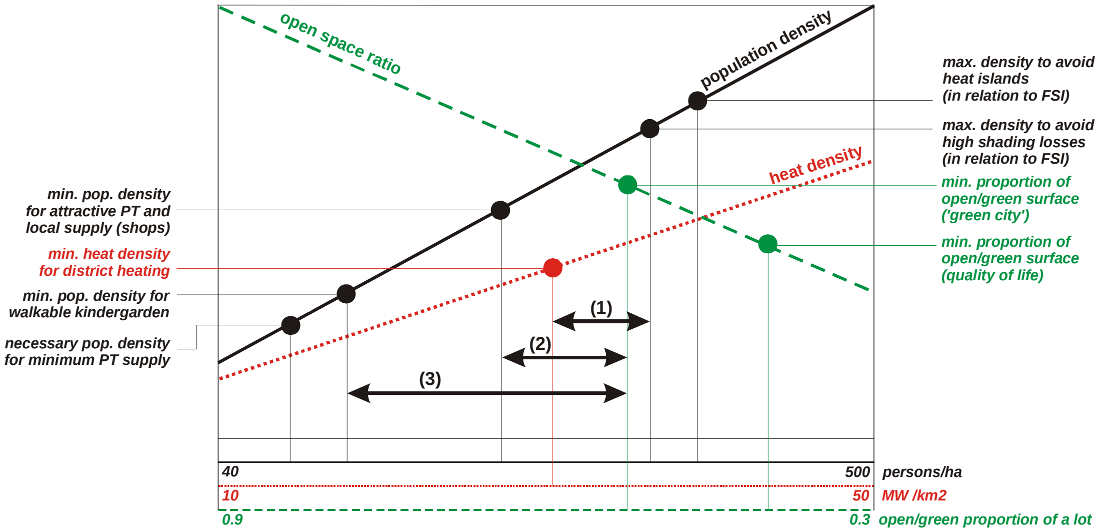
At the opposite side of this range, there are certain maximum limits to be considered in order to avoid interferences or simply negative concomitants (as shown above):

- Density of built up structures and share of open land due to the avoidance of heat islands in summer (especially in terms of cooling);
- Avoidance of high losses of solar energy due to shading (determined by height of buildings and distances between buildings);
- Provision of sunlight especially for flats (living quality, health);
- Increasing energy demand for technical systems in buildings (elevators, pumps, etc.);
- Sufficient share of green spaces within the urban environment in order to provide a high quality of life;

The following figure shall present these interdependencies in a principal sketch. Although basing on limits and thresholds found in literature roughly, it is not suggesting exact relations between considered aspects or densities.

Depending on priorities and context, varying ranges of 'appropriate density ranges' may be defined. As examples, 3 possible definitions for density ranges are indicated as there are: 'consideration of all included aspects (optimisation)' (1), green city without district heating system (2), rural settlement providing basic supply with social infrastructure and public transport (3).

Figure 40: Principle (exemplary) sketch of aspects potentially to be included in the definition of an 'appropriate' density range



Source: Own elaboration

Due to the fact, that service provision usually needs both, short distances and a certain number of customers (critical mass), it is important to define densities by integrated analyses of **density patterns together with defined catchment areas**, in order to come to densities of critical masses, which are necessary for the operation of certain infrastructure of supply[22].

For defining an appropriate density range for a specific area, the integrated consideration of those interrelations could help to support deliberate decisions for more energy efficient urban development by considering energy related aspects as well as other important (not energy related) factors and priorities.

[22] As example: A high rise building for housing is causing very high population densities within the boundary of the plot. But in case of a location e.g. at the edge of a city sourrounded by detached single family houses it might not be able to rise the average density of the area as much as it would be necessary to provide an economicallly feasible public transport or district heating for this area.

2.4.4 Practical integration of energy issues in the (spatial) planning process

In the past, there have been a few attempts to implement energy aware spatial planning in the planning process. Actually especially in Germany a number of analyses is done on spatial planning policies and spatial planning instruments and their effect on respectively their relevance for energy demand and for climate change overall in cities and municipalities at a general level (e.g. BMVBS/BBSR 2009b, BMVBS/BBSR 2009c, BMVBS/BBSR 2009d).

In the chapter at hand, selected useful solutions or suggestions on a local level shall be introduced in order to show the range of approaches, which are already developed.

Tools for the evaluation of urban development projects

As a reaction on the overall criticism on building certification systems for their not being able to include a spatial assessment, several tools have been developed. Most of those tools are extensions or additional applications of assessment or certification tools for single buildings (e.g. Energieausweis für Siedlungen, BREEAM Communities, LEED ND). Although in general, those tools may be applied for new development projects as well as for existing urban areas, it seems that it is applied mainly for new projects, either for decision-making (in advance) or for certification (as quality argument).

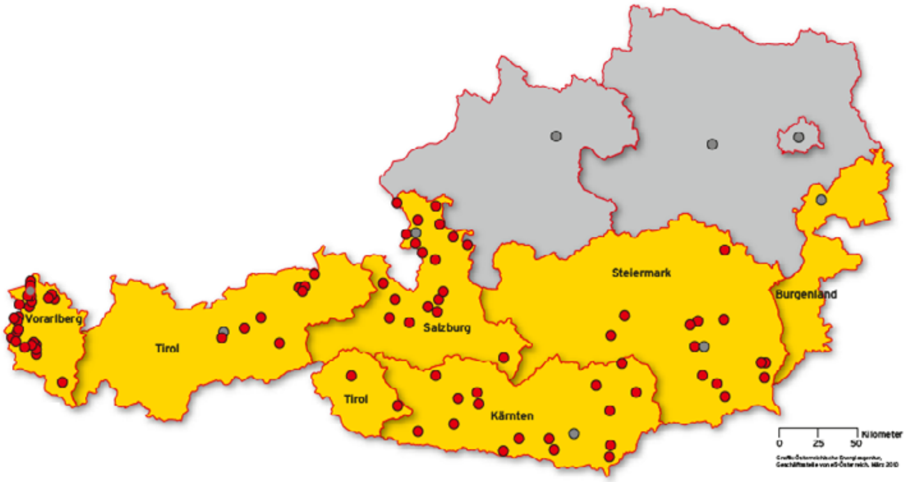
For a more detailed analysis of such tools and for an assessment in terms of coverage of relevant aspects and outcomes see further in chapter 3.

Consideration of energy aspects and integration in spatial planning documents

In general, it seems clear, that energy aware spatial planning needs both, spatial planners and energy experts. In order to be able to capture the 'whole picture' and to follow a mid- to long-term vision referring to urban development, which is as energy efficient as, possible it needs an integration of energy issues in municipal and local planning.

At municipal scale the European Energy Award has been launched, which is a European certification program for municipalities and has been implemented in several European countries already. In Austria, as one of these countries, the certification is called ‘e5 – energieeffiziente gemeinden’ (energy efficient municipalities)[23]. About 85 municipalities have joined this program, the licensed certification tool is not open to the public, and only licensed persons can apply the certification.

Figure 41: ‘e5 municipalities’ in Austria



Source: e5 2010

As activity fields for an energy efficient municipal development the following issues are defined which are open to a change by municipal actors:

- Municipal (spatial) development, land use and building permits
- Municipal buildings and facilities (municipal offices, kindergartens and schools, street lightning, etc.)
- Supply and disposal (energy, water, sewage, waste)
- Mobility (including measures to influence walking, cycling, public transport and individual motorised traffic and traffic due to municipal purposes)
- Organisation of the municipality (to enhance energy efficiency, energy officers, task force energy, cooperations, etc.)
- Awareness raising, motivation, communication and cooperation,

The certification is carried out by assessing the municipal situation referring to nearly 100 measures (with max. 10 achievable points each), which are attributed to those activity fields. Based on the assessment of the existing situation and a certification, which is done by experts of the e5 program (between ‘e’ and ‘eeeee’), a future action program is developed to define mid to long-term objectives and an overall vision for the future municipal development. Special emphasis is laid on the work of energy experts together with municipal key actors as well as education and exchange of experiences.

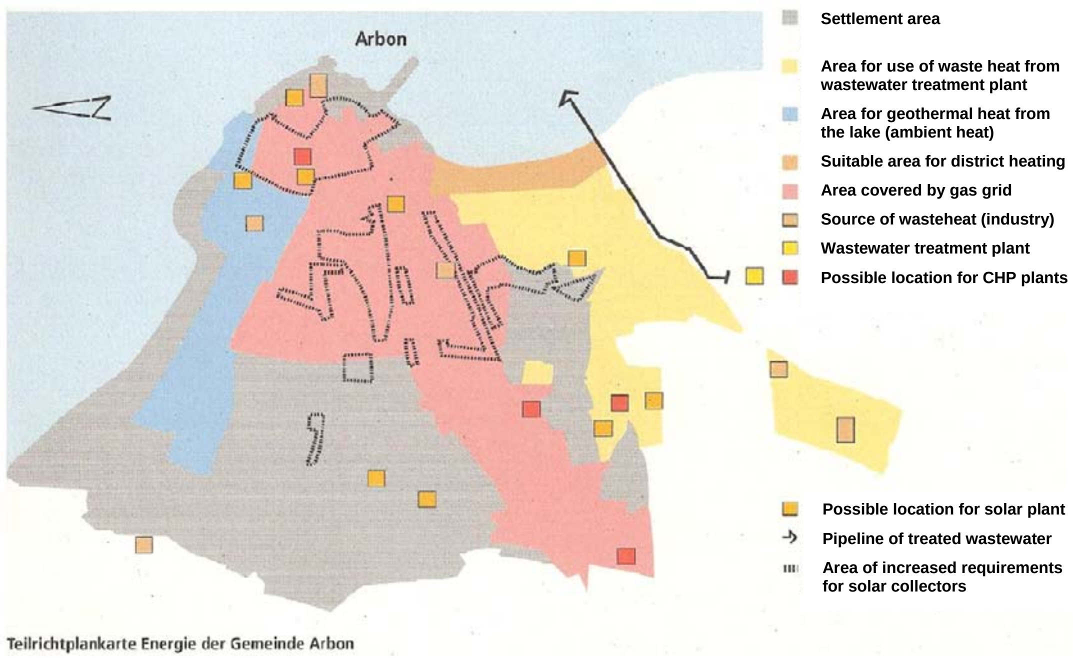
[23] The following description is based on the internet presentation of e5, available under http://www.e5-gemeinden.at/, (download 22.9.2010)

Due to the fact, that the e5-program is restricted to licensed users, it cannot be described in more detail. As far as an appraisal is possible, it seems that the program is an instrument covering varying energy aspects in the sphere of municipalities, which is valuable especially for accompanying municipalities in a common development process towards higher energy efficiency for the entire area of a municipality (also in spatial terms).

As spatial planning is usually based on guidelines and specifications laid down in maps, an integrated planning approach calls for inclusion of spatially relevant energy aspects in these basic planning tools. This is especially referring to the additional consideration of heat densities for district heating networks and available waste heat together with the accessible areas (potential consumers). Immobile sources and consumers of energy as well as areas of (existing or future) energy infrastructure (as e.g. district heat grids) shall be depicted in order to enhance more integrated planning and energy efficiency already in the phase of planning.

In Switzerland, the integration of energy issues has already been implemented in the spatial planning of municipalities. The following figure shows a spatial plan, which lays down defined prerequisites and qualities for energy use of the built up area.

Figure 42: 'Energy plan' for the municipality of Arbon (CH)



Source: Amt für Umwelt des Kantons Appenzell Ausserhoden 2006, own translation

Existing and potential energy production as well as heat sources and areas for the use of waste heat, ambient heat and district heating are defined and localised in this map (Amt für Umwelt des Kantons Appenzell Ausserhoden 2006, Öffentliche Baselbieter Energieberatung 2005). In laying down these predefinitions and requirements it is possible to visualise the principals of a future vision on energy provision in the municipality. Today's (and tomorrow's) municipal actors and inhabitants are able to adapt their plans to this overall strategy.

Finally – at a more local scale, for medium to large urban planning projects – the calculation in an optimisation model is stated to be useful in order to balance solar energy gains and losses within the planned area.

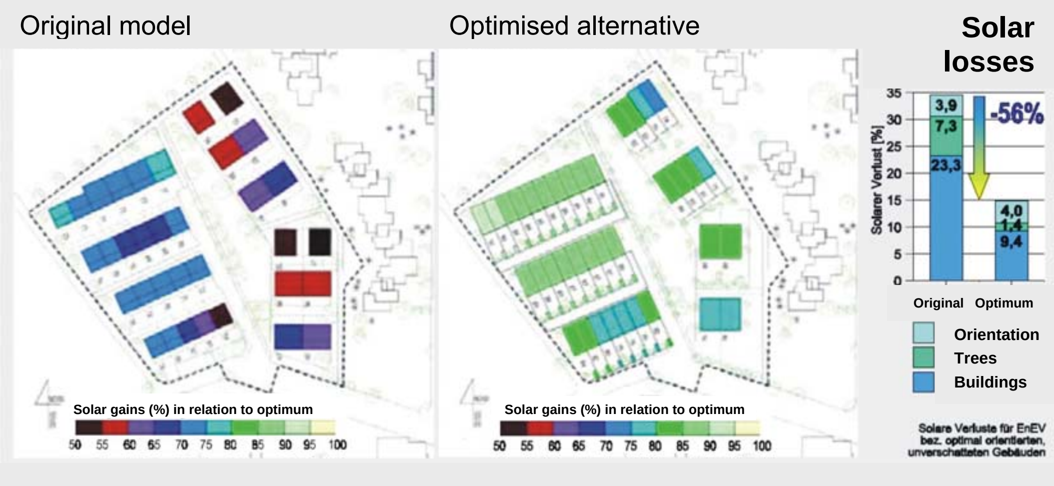
As an example for optimisation at the local level (of construction plans) the German tool GOSOL[24] can be introduced, which is calculating an optimisation of solar energy gains for new developments of a certain size. Certainly for the application of this tool a lot of local information is needed to build up the model. The 3-dimensional computer model includes a digital model of the topography (of the project area as well as of the surrounding area), location and building envelop of existing buildings (to calculate shading) and planned buildings as well as location and type of vegetation (again to calculate shading).

With this information, the tool is able to calculate the balance of solar gains and losses for a specific development project and for existing buildings as well as to compare different scenarios of development. As an outcome of this calculation hours of sunshine, solar gains and expected specific energy demand for space heating can be presented. The following figures show these interrelated aspects of the solar optimisation for two alternatives.

The first comparison (fig. 43) shows the outcome in terms of solar losses due to shading for two alternatives of local construction, which seem not too different at first glance. Nevertheless by changing the construction plan of those buildings in the way the optimisation suggests solar losses can be reduced to less than the half of the original model.

[24] Based on program description available under http://home.arcor.de/gosol/gosol.htm, Goretzki 2010 (download 21.9.2010)

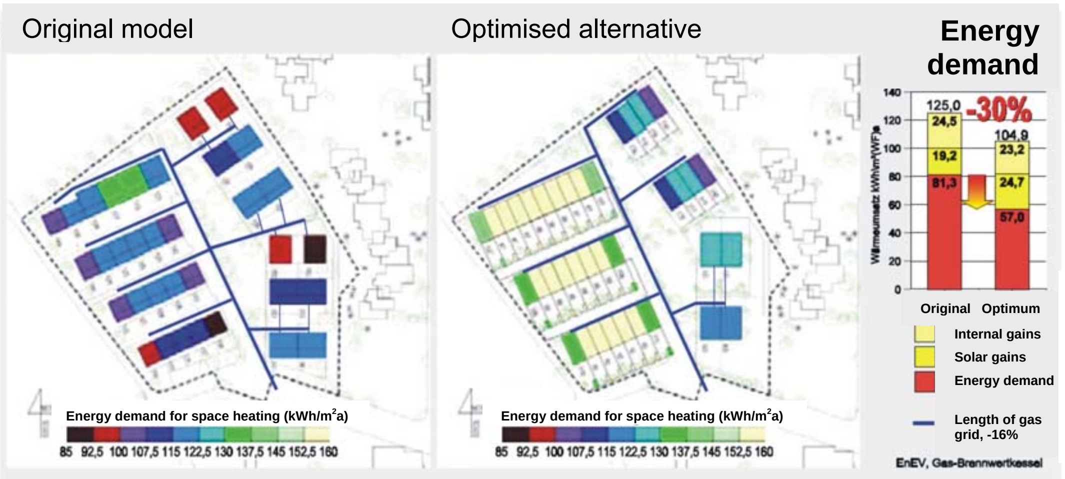
Figure 43: New urban development - Optimisation in terms of solar losses (shading)



Source: Goretzki 2008, own translation

The following figure presents the same alternatives and their outcomes in terms of specific heat demand (considering building envelops and standards, orientation and shading). Due to the higher solar gains together with the abandonment of detached buildings and a construction with slightly better volume-to-surface ratio, the specific energy demand of the alternatives is about 30% lower than the one of the original model.

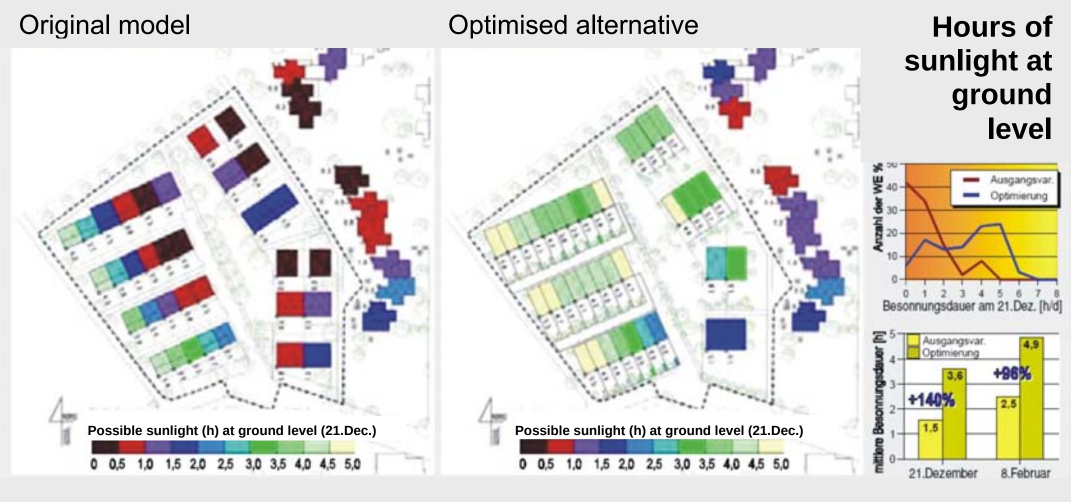
Figure 44: New urban development - Optimisation in terms of energy demand for space heating (due to passive solar gains)



Source: Goretzki 2008

The third figure (fig. 45) shows the results in terms of sunlight hours in flats at ground level. This comparison not only comprises energetic optimisation, but also an important enhancement in terms of health and personal comfort. The optimised alternative again shows considerably better values, as the hours of sunlight increase for 140% in the winter season and still nearly double in summer.

Figure 45: New urban development - Optimisation in terms of hours of sunlight in flats at ground floor level



Source: Goretzki 2008, own translation

Hence the application of this tool can contribute to reduce energy demand considerably, but it is dependent on certain prerequisites. The application is only feasible for a larger area of planning with common decision structures, which are able to definitively decide upon buildings characteristics of buildings together (e.g. location, volumes and envelops).

2.5 Future development options in context with spatial and urban framework conditions

Urban development takes place in varying contexts with high relevance in terms of the appraisal of spatial changes and the range of options for future development. Thus it has to be analysed together with the existing framework conditions.

Referring to energy aware spatial planning some factors have to be considered in relation to the appraisal of the existing situation as well as relating to options for future development.

In order to relate the range of measures in the sphere of spatial planning to its possible context, aspects of outstanding importance shall be highlighted briefly in the chapter at hand[25].

[25] As already mentioned in the introductional chapter, urban development and spatial planning is mainly focussing on housing and services in the study at hand. Industry is taken into consideration only in case of an important relation to those sectors (as e.g. in terms of use of waste heat).

It has to be stated, that the share of industries and the industrial sector is decisive for the energy use of a municipality as well. Nevertheless this is not taken into consideration in the study at hand.

Size of a municipality (mega city versus village)

The size of municipalities is especially important in terms of energy demand for transport. Differences due to the size and regional location of a municipality have been analysed in several studies on aspects of energy demand in urban and rural municipalities (e.g. Ott et.al. 2008, Tappeiner et.al. 2002, Deilmann/ Schiller/ Siedentop et.al. 2009, ARE 2006).

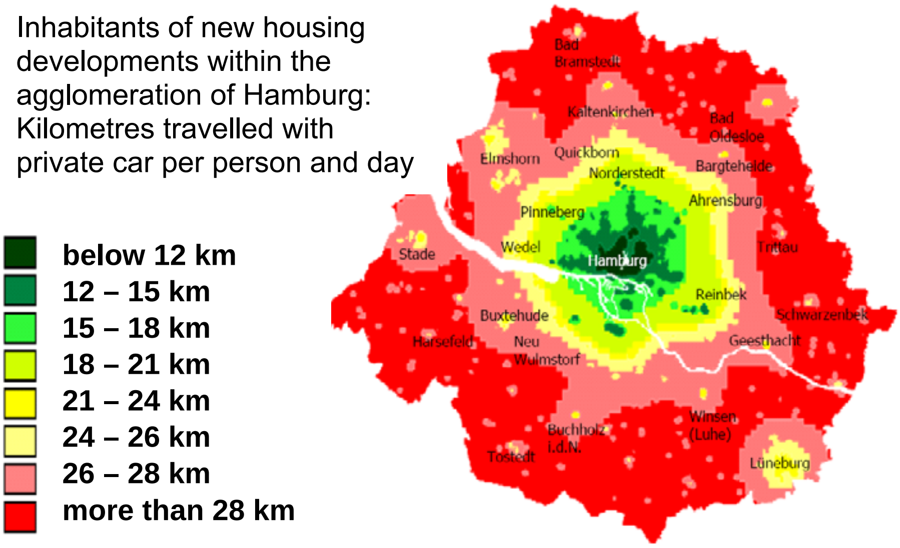
Ott et.al. (2008) point out the relevance of size and type of municipalities referring to the energy demand for home induced mobility (commuting, education, shopping, business, leisure, accompanying traffic). It is summarised, that there are inter-relations between energy demand for mobility and location and size of the municipality as follows:

- Distances covered by people living in centrally located housing areas (mainly in cities and agglomerations) tend to be shorter.
- Referring to primary energy consumption from home-induced mobility, the importance of the type of municipality is very high with differences of more than factor 4.
- Main differences between urban and rural municipalities have to be stated in terms of leisure transport, commuting and shopping due to fewer opportunities in smaller villages and rural areas and thus longer distances to be covered.

Thus, centrality has to be seen as an important factor having a considerable effect on the 'outside-orientation' of a municipality (Tappeiner et.al. 2002).

The following figure again presents the relevance of location of housing in terms of centrality. Inhabitants in areas of higher centrality clearly tend to travel less than the population located in rural areas and small villages.

Figure 46: Kilometre travelled with private car per person and day (for the example of Hamburg agglomeration)



Source: Deilmann/Schiller/Siedentop 2009, own translation

With reference to a study by Ewing and Cervero, Handy (2005a) presents findings on elasticity of changes of regional accessibility (derived from a gravity model) on energy demand for mobility (vehicle miles travelled), which point out notable effects. According to these findings a 10% change of regional accessibility is related to a 2% decline of vehicle miles travelled.

Nevertheless, the interrelation of VMT with the regional setting is of very limited relevance since single municipalities cannot decide upon regional accessibility. Whereas the modal choice of this traffic might be altered (as i.e. by supply with attractive public transport), the principal question of allocation of different opportunities due to centrality stays inherent (different social, cultural, educational and job opportunities in villages in contrast to cities or metropolises).

Additionally to transport issues, the question of densities has to be handled in a varying way depending on the overall size of the respective municipality. High densities are rather appropriate (and accepted) in large cities and metropolises with a certain centrality and high level provision with various public and private facilities. In contrast to the situation in agglomerations, an appropriate maximum density has to be defined more carefully in smaller (growing) cities and villages in order to provide the possibility to construct additional (acceptable) living space. Even though, urban development should bear in mind minimum densities as well also in small municipalities (see further chapter 2.4.3).

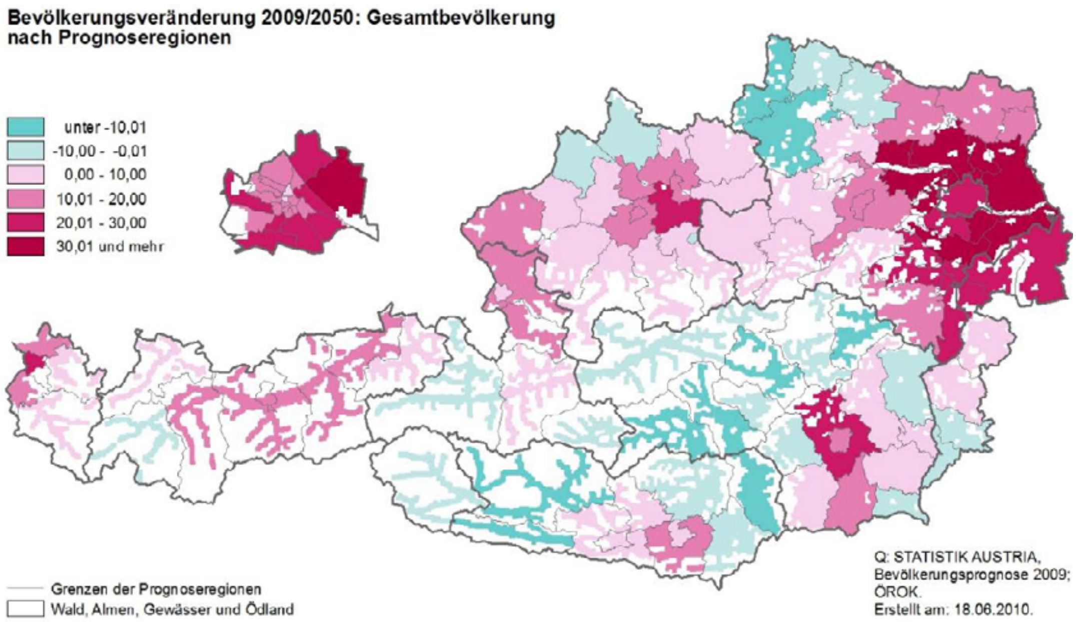
Future population development

The future population development to be expected is of outstanding importance for the appraisal of different measures of spatial planning.

Until 2050 Austrian population development is expected to differ widely between urban agglomerations and rural areas. According to the actual official forecast, a further movement towards agglomerations is expected, whereas most of rural areas are expected to loose population (Hanika 2010).

Thus municipalities located in these areas have to face a situation, which is considerably different from that of municipalities in growing regions.

Figure 47: Population development in Austria 2009-2050



Source: Hanika 2010

Referring to spatial planning and its impact on energy issues, population change is especially important in terms of

(1) the appraisal of new urban development projects and
(2) the situation of existing and future common, efficient energy service provision (public transport, district heating).

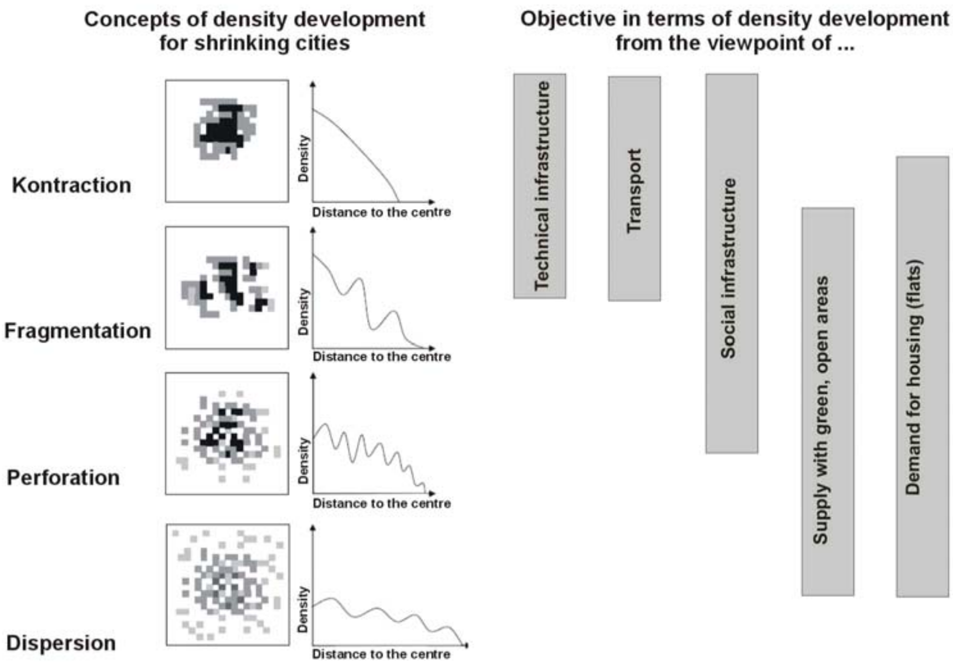
In terms of the appraisal of new development projects it is important to keep in mind the background of expected population growth while evaluating a certain development. Whereas in growing municipalities new developments can be seen as necessary part of the overall municipal development, this is not the case in shrinking municipalities. From an overall point of view, new development projects (as well as large zoning changes) in case of decreasing municipal population have to be questioned and compared against alternative measures of renovation and rebuilding measures within existing structures.

Referring to options for common, efficient energy service provision, it is especially important to analyse developments also in case of shrinking population. Whereas in growing municipalities (in terms of population development) density is mainly a question of new developments, dealing with density is more sensible in shrinking municipalities.

In context with a declining number of inhabitants built structures become vacant to a much higher extent (not only related to attractiveness of quarters). Westphal (2008) has defined four concepts of density developments in shrinking cities, pointing out different objectives respectively difficulties in relation to infrastructure provision, transport, social infrastructure, open space and demand for places of residence.

Whereas developments of concentration (or 're-dedensification') and (to a lower extent also) fragmentation minder favourable conditions for infrastructure and public transport provision less, the concepts of perforation and dispersion clearly provoke a critical situation.

Figure 48: Concepts of density development in shrinking cities and related issues



Source: Westphal 2008, own translation (redrawn)

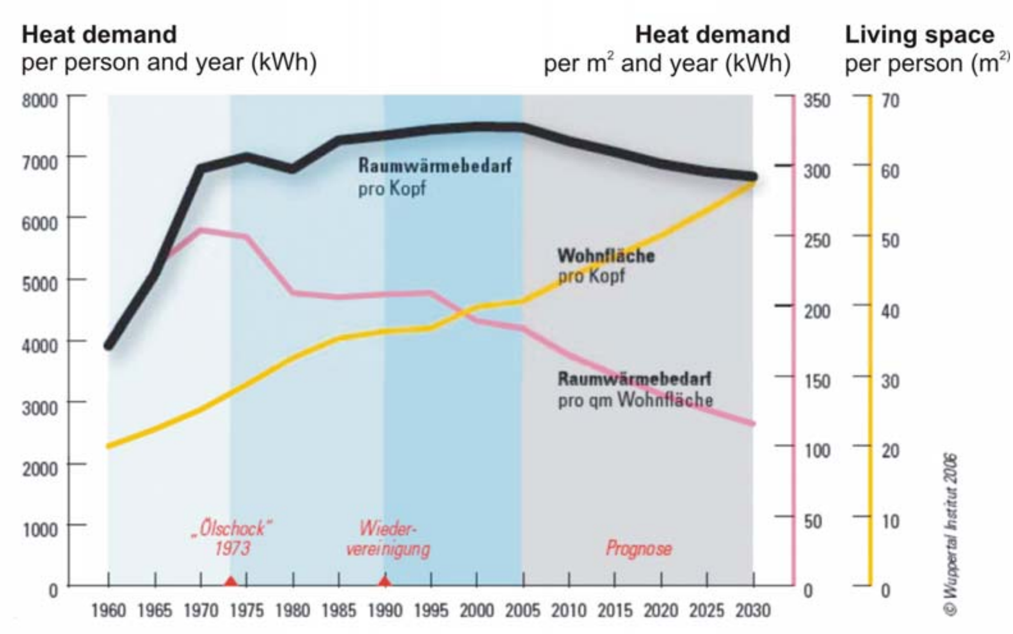
Thus referring to infrastructure provision and transport issues, the first two concepts are clearly to be favoured against developments of perforation or dispersion.

Nonetheless, usually those developments are left to the market, spatial policies (to direct such developments) are difficult mainly due to scattered ownership structures and there is no broad implementation of such policies[26].

Decreasing heat demand due to building and renovation standards (decreasing heat densities)

Another topic with relevance to energy issues is the general trend of decreasing energy demand for space heating. Despite increasing living space per capita, the total demand for space heating was nearly constant in the past 30 years, due to decreasing specific heat demand (per m^2) in the same period (see following figure). A further ongoing substitution of decreasing specific heat demand (per m^2) by increasing living space is expected also for the future development in Germany (Fischedick/Nast/Bohnenschäfer 2007, Hanke/Schüle/Pietzner 2007).

Figure 49: Heat demand for space heating in the context of the change of insulation standards and living space per capita (example Germany 1960-2030)



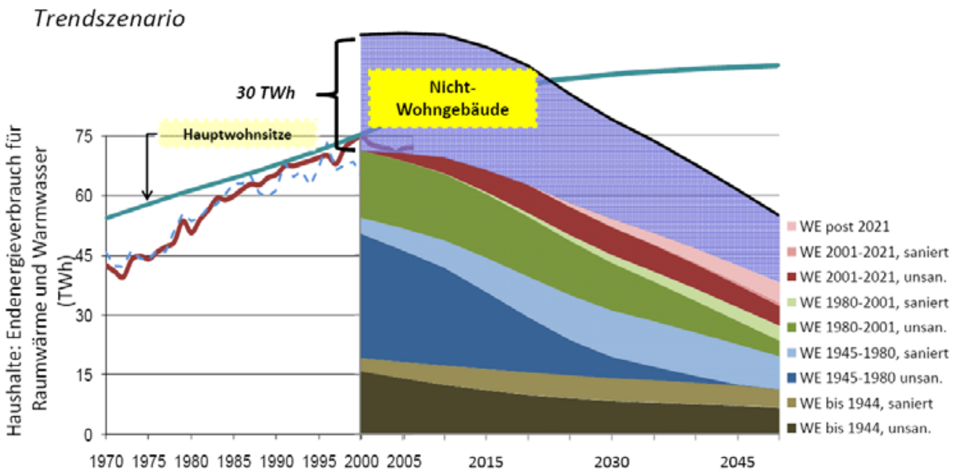
Source: Fischedick/Nast/Bohnenschäfer 2007, own translation

Despite the fact, that further increase of living space per capita is to be expected, the total energy demand for space heating in Austria is expected to decrease considerably in the future due to still higher rates of energy efficiency in the housing

[26] In Germany the issue of ‘shrinking cities’ have become a topic after the start of population decline in Eastern Germany, where a number of cities as well as rural areas are confronted with this development to an outstanding extent. Although there are regions in Austria, where similar developments are observed and a further spread has to be expected in the future, this is not a topic to broad discussion in Austria so far. Only few communities have been dealing with spatial planning due to shrinking population as e.g. Eisenerz (http://www.eisenerz.at/redesign/).

sector (renovation and new buildings). As presented in the following figure, which points out the total heat demand for space heating and hot water of buildings of different construction periods (in original condition and renovated), in Austria a reduction of more than -40% is expected until 2050.

Figure 50: Heat demand for space heating and hot water – Austria, trend 2000-2050

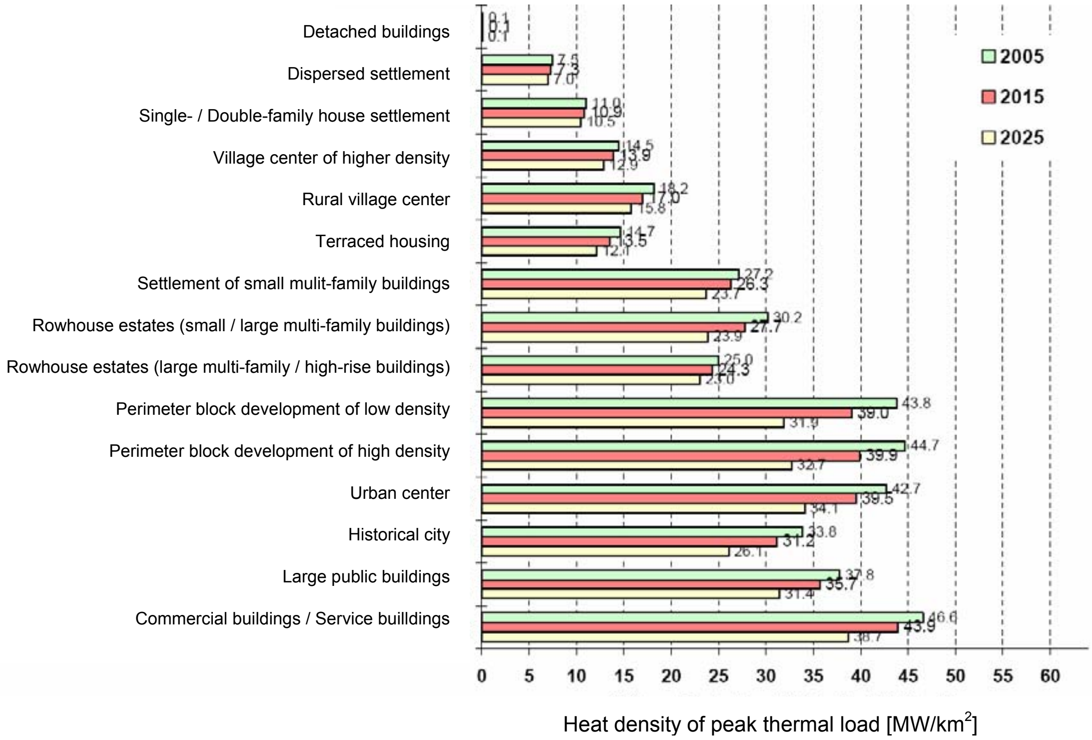


Source: Müller 2009

This – in principle advantageous development – may increasingly lead to difficulties in the context of the reduction of heat density in certain areas with existing district heating systems. As shown in the following figure, changing heat densities have to be expected already until 2025, a decrease is expected in all types of settlement structures.

Thus the economic feasibility of district heating systems, which are hardly efficient from an economical point of view today, will be further reduced in near future. Especially in rural areas it will be necessary to set counteracting measures in order to avoid serious consequences.

Figure 51: Development of heat-density demand in different settlement structures 2005-2015-2025



Source: Blesl 2008

Assessment of spatial planning measures in the context of specific framework conditions

Overall it has to be stated, that in reality the complex mix of varying contexts makes it difficult to forecast the effect of specific measures or even compare the outcome of such measures after implementation.

General interrelationships (as presented in chapters 2.2 and 2.3) have to be critically assessed against the existing framework. Most difficult in relation to this question is the fact, that there is no direct comparison possible. Effects on energy demand by spatial planning under different conditions can only be estimated and simulated; a 'reality check' by transformation usually needs decades. The comparison of two options under the same conditions is not possible due to differing framework conditions in every location.

Thus decisions on spatial developments have to be taken from case to case, considering the guidelines defined above, but at the same time critically analysing the relevance and validity of those planning principles and the options to trigger a development towards the aspired direction.

2.6 Relevance of energy aware spatial planning for the development of communities

Even though energy demand and energy efficiency are to be seen as important issues in the context of climate change mitigation (by reduction of GHG emissions), which can be influenced by municipalities considerably a range of other tasks is important for a sustainable municipal development as well.

In 1987 the World Commission on Environment and Development agreed on a definition of sustainable development (Brundtland Report) as:

> *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs "* (UN Commission on Environment and Development, 1987)

Austria has also signed the "Declaration of Rio on Environment and Development" (1992), in which three dimensions of sustainable development were laid down: environmental protection, economic growth and social development (United Nations Conference on Environment and Development 1992). It can be stated, that – although stronger related to environmental protection - energy aware spatial planning is covering also the two remaining dimensions to a certain extent:

- Environmental protection is covered by contributing to mitigation (less energy use for space heating and for mobility), but also by contributing to less additionally used and sealed land for built up structures (due striving for higher densities of built up structures in average); the interrelationship with this dimension of sustainability is described detailed in chapters 2.2 and 2.3.
- Economic growth (respectively cost efficient municipal development) is supported by settlement structures which are more efficient;
- Social development is supported in terms of reducing costs for space heating (also in short term) and enhancing favourable urban structures for walking, cycling and the supply with public transport (medium to long term); this allows for alternatives in transport and thus provides with a chance to lessen fuel poverty potentially caused by increasing (fossil) energy prices[27];

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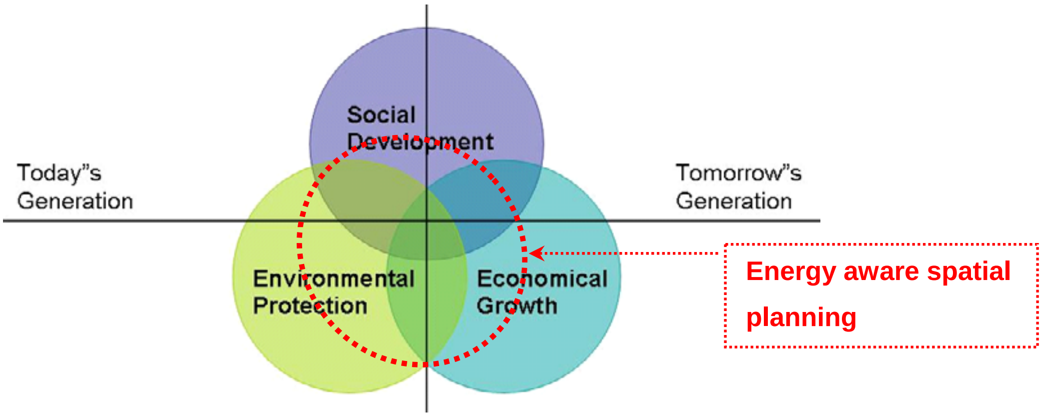
[27] Fuel poverty can be defined as a situation due to rising fuel costs, in which one is not able to pay for energy as much as needed (e.g. for heating the living space or for driving a car).

Figure 52: Sustainability and its 3 dimensions



Source: http://www.unngosustainability.org/CSD_Definitions%20SD.htm (download 23.6.2010), own adoption

Referring to the economic point of view (in terms of communal budgets) there is a considerable accordance between the aim for higher densities to be able to supply public transport services, local supply and district heating networks with the issue of cost for technical respectively linear infrastructure supply (e.g. supply with water, natural gas and electricity, sewage).

A number of studies (e.g. Siedentop/Schiller et.al. 2006a, Siedentop/Schiller et.al. 2006b, Suter et.al. 2000, Tappeiner et.al. 2002) on the relation between urban development and infrastructure costs point out a high increase of the length of linear infrastructure and according costs between single family house developments and developments of higher densities (with big differences already starting with terraced housing and medium-rise apartment buildings). Thus energy aware spatial planning additionally supports cost saving municipal development to a considerable extent.

In terms of the social dimension of energy aware spatial planning, some measures are able to provide the chance for support of less wealthy persons. Measures with effects on the transformation to an environment, which is favourable for walking, cycling and public transport provide with the possibility for using more environmentally friendly modes of transport (optionally or for less wealthy persons i.e. due to the lack of a second family car). Additionally such structures (and their inhabitants) are also able to overcome a change to a post fossil future (including increasing fuel costs) more easily than car oriented neighbourhoods.

Referring to buildings it is mainly the danger of fuel poverty caused by increase of energy prices, which has to be expected to increase costs also for space heating. It is obvious, that a reduction of the energy demand needed will lower costs (per m^2, even after considering rebound effects) respectively helps to keep living space warm to a more affordable price. Additionally, the provision of heat e.g. by a (biomass based) district heating network can help to avoid rising costs.

Concluding, as mentioned above, in addition to (energy aware) spatial planning, there are a large number of other issues and tasks for communities to deal with in the context of communal organisation and development. In addition, some measures might cause additional costs, which have to be covered by the municipal budget[28].

As valid for sustainability in general, there is an area of synergies between the three dimensions of sustainability as there are also potential conflicting targets also for the specific case of energy aware spatial planning and its relation to other issues and objectives for a sustainable development of communes as well.

In fact, it is not feasible to define a general – neither higher nor lower – weight of this issue against other questions in the context of municipal development. In case of conflicting targets and/or limited budgets, objectives and priorities have to be analysed and balanced to each other.

28 Although this is stated to be of minor relevance. Energy aware spatial planning is characterised by considering additional factors in phases of decisions. Alternatives do not have to be more extensive. In long term even cost savings can be expected due to lower costs for infrastructure provision (e.g. water, sewage, roads etc.)

3 Selected Tools for Assessment and Certification

3.1 General information on selected tools

In this part, an analysis of assessment tools on the relation of spatial planning and energy issues (explicitly or amongst other issues), which have been developed in Austria and other countries, allows for an overall comparison of already available tools. It seems clear, that a tool for assessment of the complex relation between spatial planning and energy issues can only cover a part of the interrelationships lying behind. Nevertheless, there have been several attempts to capture those relations and to develop tools for estimating or rating overall energy demand and energy efficiency of settlements as a decision support for municipalities and as certification for development projects. The findings from literature review (as described above) are used as a sound background for analysing and assessing the relevance and options for the use of such tools in order to support energy aware spatial planning.

The following tools have been selected for further analysis:

- Energieausweis für Siedlungen (Emrich, AT)
- EFES - Energieeffiziente Entwicklung von Siedlungen, energy efficient development of settlements (ÖIR, AT)
- LEED ND - Leadership in Environmental and Energy Design – Neighbourhood Development (US Green Building Council)
- BREEAM Communities – BRE Environmental Assessment Method for Communities (BRE, UK)

As a general difference, varying objectives and approaches have to be stated especially between the two calculation tools – ‘Energieausweis für Siedlungen’ and ‘EFES’ and the two certification systems – ‘LEED ND’ and ‘BREEAM Communities’. The calculation tools predominantly comprise an analysis of spatial issues and their effect on energy demand and quantified estimations of those effects. The certification systems, in contrast, present a comprehensive analysis of not only spatial issues but an analysis together with environmental and social framework conditions and impacts. The rating is done mainly qualitatively; there are no quantified results to be presented. Due to the emphasis of the work at hand, non-spatially related parameters are mentioned, but not further analysed in detail.

3.2 Energieausweis für Siedlungen

The ‘Energieausweis für Siedlungen’ (energy certificate for settlements) has been developed by order of the provincial government of Lower Austria as an addition to the energy certificate of buildings (as regulated by EPBD 2002, in Austria this directive was set in force in 2006).

It is available from the projects homepage (www.energieausweis-siedlungen.at), the application of the tool is subsidised by the provincial government of Lower Austria, but there is no obligation to provide the certification by municipalities, so in principle the tool is rather depicting a rating of settlements and awareness raising for municipal actors than a binding certification.

The following description is based on information from the homepage (see above), from the instruction manual (Emrich et.al. 2009) and from the excel-tool itself (version 1.4.1, Emrich et.al. 2010).

3.2.1 Scope and objectives, system boundaries

As an overall aim for developing this tool it was defined to be used as decision support for municipal actors

- to optimise settlement structures from an energetic standpoint and
- to reduce costs (due to provision of public infrastructure, which is particularly important for municipalities).

The level of analysis is parts of municipalities (both planned and existing settlements).

By using the tool, the total energy efficiency of a settlement shall be demonstrated; it is possible to compare different alternatives and/or different locations to each other.

Due to its function of a complementary tool to the energy certificate for buildings, the ‘Energieausweis für Siedlungen’ does not consider parameters covered in the energy certificate for buildings. It is stated by the authors, that most of the regulations laid down at the level of the local construction plan are expected not to effect parameters, which are analysed in the energy certificate of buildings. The certificate is presuming a building standard (for new buildings) which enables the building owner to obtain high housing subsidy (in Lower Austria).

Table 10: General description of 'Energieausweis für Siedlungen' (AT)

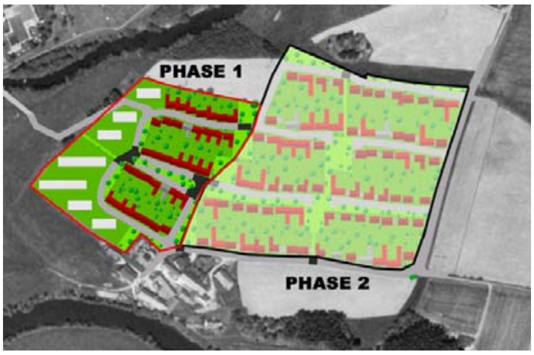
Name and author	Energieausweis für Siedlungen (Emrich Consulting)
Characterisation	Rating for development projects in terms of energy efficiency / energy demand and costs for infrastructure
Main issue	Energy efficiency due to location, settlement structures and local infrastructure (building related energy efficiency excluded)
Spatial units (size of analysed areas)	Projects for new settlements, minimum/maximum size not defined precisely (example given for 3,5 ha)
Level of analysis	Precise planning at plot level, detailed information and data on the analysed area and the municipality needed
Time horizon (existing / planned areas)	Developed as decision support for new (planned) areas, application possible for existing and planned areas
Topics analysed	Local infrastructure, quality of open space, accessibility, location and building (development), estimation of according costs
Access to the tool	Public, excel-based (table for download)
Consideration of interdependencies with a larger area	Only consideration of public social and technical infrastructure outside the analysed settlement
Results	Quantitative and qualitative results: - Costs for local infrastructure (per accommodation unit/year) - CO_2-emission from traffic (per accommodation unit/year, without commuting to work) - Quality of location and buildings (factor) - Land consumption (per accommodation unit) - Qualitative score as final result, according to electric appliances and building related energy efficiency assessment (A to G) Comparison with a (good) example and a conventional settlement structure included
Comparison of alternatives	Possible if information is available for alternative locations
Further information	www.energieausweis-siedlungen.at

Source: Emrich et.al. 2009

3.2.2 Inputs and evaluation criteria

The tool is structured into several excel sheets, which shall only need between 30 minutes and 2 hours to be completed. As background information a blueprint of the area is necessary as well as detailed data on the settlement and the community in which the analysed settlement is located (e.g. distances to social infrastructure facilities).

Figure 53: Example of blueprint needed for applying ‘Energieausweis für Siedlungen’



Source: Emrich et.al. 2009

The calculation needs data on local technical infrastructure, quality of open space, accessibility of social infrastructure and public transport and information on topography, type of buildings and orientation of buildings (see table below). In addition, the sheets contain an estimation of costs according to the technical infrastructure needed estimated on the basis of local construction plans and building types.

Table 11: ‘Energieausweis für Siedlungen’ - Assessment criteria related to spatial planning

Criteria	Relevance in assessment
Length of technical infrastructure – traffic, water, sewage, electricity, number of lights, district heating/cooling	used for cost calculation
Need for a noise protection wall	used for cost calculation
Private green space	leisure traffic - indirect energy for transport
Quality of open space – share of attractive foot paths, private gardens, wide streets and friendly design, traffic calming	leisure traffic - indirect energy for transport
Quality of open space – source of noise within 150 m	leisure traffic - indirect energy for transport
Accessibility and transport – distance to nearest public infrastructure and important functions (centre, local supply, playground/green space, kindergarten, primary school, public transport, large green area, swimming bath, sports ground, leisure/cultural facilities)	distance and modal split - energy for transport
Accessibility and transport – interval of public transport services	modal split - energy for transport
Location and buildings – topography (basin, summit/north slope, west-/east slope, plain, south slope)	building related energy efficiency and use of renewable energy (qualitative)
Location and buildings – type of buildings (single family house detached, coupled single family house, terraced housing, multi-family houses)	building related energy efficiency and use of renewable energy (qualitative)
Location and buildings – orientation (of living rooms, south, south-west, southeast, west, east, northwest, northeast)	building related energy efficiency and use of renewable energy (qualitative)

Source: Emrich et.al. 2009

According to the objective as practicable decision tool for municipalities, the data needs are manageable and relatively easy to assemble (for municipal actors involved in the planning process).

Nevertheless, in general there are rather few criteria considered for assessing the energy efficiency of a settlement. Additionally, there have to be stated some specific critics:

- The quality of open space is considered only within the analysed settlement (private gardens), whereas the characteristics of the surrounding area are taken into account solely for leisure activities at weekends. This might lead to underestimation of available open space during the week (e.g. if there is an attractive open space or a park nearby). Furthermore the direct deduction from private gardens and attractive walking infrastructure within the analysed area on leisure traffic seems rather unsecured.
- The analysis of current public transport services (intervals) for planned settlements might lead to false results due to the fact, that public transport services often react on demand (implementation of public transport after settling in); furthermore a direct causality between the quality of public transport supply and the modal split caused by the analysed settlement is stated to be questionable.
- Referring to the orientation of buildings, it specified, that living rooms do not face the street, thus the opposite side of a house shall orientate to south. This seems not necessarily plausible e.g. for traffic calmed residential areas.

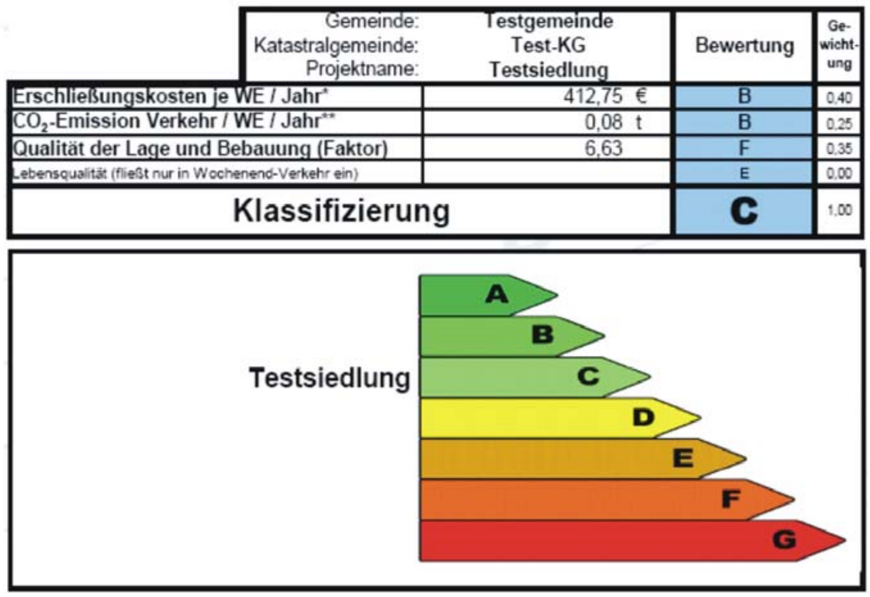
3.2.3 Outcome and results

The outcome of the tool is presenting three different final results (without allowing insight to the calculation laying behind), including:

- Costs for infrastructure (€ per housing unit and year as a mean value)
- CO_2 emissions due to transport (per housing unit and year)
- Quality of location and buildings
- Quality of leisure areas is presented, but used only as a factor for leisure mobility affecting the calculation of CO_2 emissions, thus it is not included in the total classification.

For those results a quantitative presentation as well as a graphical classification is presented as shown in the following figure. According to the Austrian energy certificate for buildings, each of the results is classified with a code between ‘A’ and ‘G’. The code ‘A’ stands for the most efficient use of resources, whereas ‘G’ depicts the worst rating (see below).

Figure 54: Classification of settlements as result of the tool ‘Energieausweis für Siedlungen’

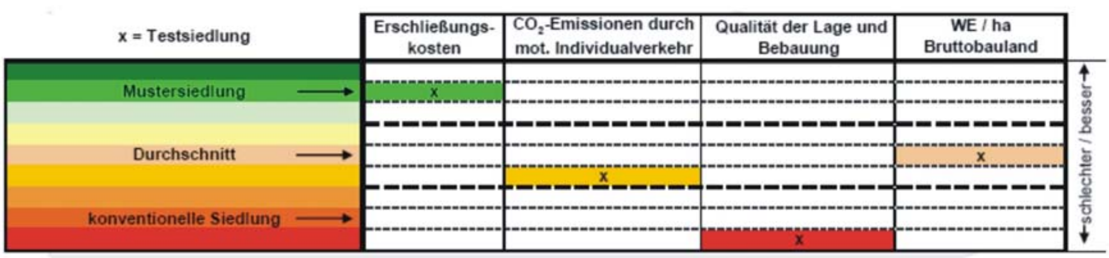


Source: Emrich et.al. 2009

In a second step, a comparison of the analysed settlement is presented to the values of an, average Lower Austrian reference settlement’ and to a settlement, which is stated to be very resource efficient. This comparison allows for relating the outcomes for a specific settlement to reference settlements.

This comparison is presented in a figure, in which the analysed settlement is placed within the range of the average reference settlement (low resource efficiency) and the highly resource efficient settlement in terms of costs for infrastructure, CO_2 emissions due to transport, quality of location and buildings and density of housing units.

Figure 55: Graphic presentation of the comparison with reference settlements - result of the tool ‘Energieausweis für Siedlungen’



Source: Emrich et.al. 2009

Additionally, there is a calculation of ‚scenarios’ in which values of the analysed settlements are extrapolated on the land reserved for expansion (areas dedicated for buildings but not built up yet) within the municipality as well as within the district. Thus - with costs of infrastructure, CO_2 emissions and number of housing units as calculated values - this extrapolation points out the (theoretical) effects of filling up all available areas with the analysed building type.

3.2.4 Evaluation in relation to specified topics of energy aware spatial planning

The following table presents the coverage of the analysed tool by the comparison of specified relevant topics and interrelationships for energy aware spatial planning (see chapters 2.2 and 2.3) and the topics and interrelationships considered by using the analysed tool.

It has to be stated, that only a small number of relevant interrelations has been chosen to describe the total energy efficiency of a settlement.

Table 12: ‘Energieausweis für Siedlungen’ – overview on considered guiding principles by the tool

	Topography	Location, mun. shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Minimising (heat) energy losses	general wind regimes hilltops and basins wind shading avoidance of north slopes			sufficient green space use of shading	building types		aerial situation	
Maximising (passive heat) energy gains	avoidance of sun shading			passive solar use options		orientation to south avoidance of sun shading		
Use of renewable energy sources	active solar use options			active solar use options	use of renewables	active solar use options		
Energy service pro-vision *Built environm.*			heat sources and consumers		district heating densification cert. locations			
Mobility		development near PT	mixed funct. (PT demand)		options for PT			
Minimising vehicle miles travelled (VMT)	avoidance of steep slopes	short distances avoidance of dispersed settlements compact shape	mixed funct. (supply, shops)	sufficient green space	options for local supply			avoiding detours attr. design and security

.... considered .... partlyl/indirectly considered .... not considered

3.2.5 Resume

Overall, following the defined main aims by the author respectively the provincial government of Lower Austria, the tool points out a certain sustainability level from the viewpoint of energy efficiency as well as of economic effects due to infra-structure demand. Although stating the tool to present the total energy efficiency of a settlement, the tool is depicting rather a combined analysis not only of the energy relevance of settlements' characteristics but also the according communal costs. As shown above, the results of the 'Energieausweis für Siedlungen' are basing on a relatively small number of criteria.

Consequently, the final classification is composed of the results of the three main fields of investigation, but with different weightings. Costs of infrastructure contribute with 40%, CO2 emissions from transport with 25% and quality of location and buildings with 35% to the final classification.

Thus, from the standpoint of energy aware planning assessment, it has to be stated, that the tool is highly (infrastructure) cost driven and mixes arguments for energy aware spatial planning with arguments for economically sustainable municipal development.

Even if these infrastructure costs can be widely argued as indirectly describing resource use and e.g. energy losses, this circumstance has to be considered in the comparison with other tools. Referring to the technical infrastructure, the existence of district heating systems is contributing to the assessment only as cost indicator for the municipality – due to relatively high costs of district heating infrastructure this is rated negatively – which is not congruent with the results of the literature review shown above (district heating systems as energy efficient systems under certain conditions, especially dependent on heat densities).

Nevertheless, from the viewpoint of application barriers it is stated to be a useful tool for awareness rising especially of municipal actors due to its low-threshold, easy use and quick implementation possibilities.

3.3 EFES

'EFES - Energieeffiziente Entwicklung von Siedlungen' (energy efficient development of settlements) has been developed in the course of an Austrian research project (research programme 'Neue Energien 2020', www.neue-energien-2020.at). An important task of the project is the development of an energy rating tool, which is analysed in the master thesis at hand. The EFES-tool will be available from the projects homepage (www.energieeffizientesiedlung.at) in the end of 2010.

The following analysis and description is based on information from the homepage (see above) and from an excel-calculation sheet, which is a preliminary version of the excel based tool under work (Dallhammer et.al. forthcoming).

3.3.1 Scope and objectives, system boundaries

As objective of the project the analysis of energy efficiency of settlements (already built up parts or planned areas of municipalities) in terms of structures and patterns of buildings and traffic relations due to the location of the analysed settlement is defined. In addition, the project analyses relevant policies and measures in terms of their influence on the energy efficiency performance of built up structures in order to come to recommendations for settlement policies in Austria for enhancing energy efficient development.

Table 13: General description of 'EFES' (AT)

Name and author	**EFES - Energieeffiziente Entwicklung von Siedlungen**
Characterisation	Rating for existing settlements and development projects due to an estimation of the total energy demand
Main issue	Energy efficiency due to building standards, mobility (in context with settlement structures) and the optional contribution of local renewable energy
Spatial units (size of analysed areas)	Minimum/maximum size is not predefined, due to a relatively high need for data (at the level of single buildings), the size of the rated area is in principle limited by time and effort resources
Level of analysis	Precise planning at building and plot level, detailed information and data on the analysed area and the municipality needed. Based on the results from another research project data on renewable energy is already included (for Austria).
Time horizon (existing / planned areas)	Developed as tool for municipalities to rate the energy demand of certain settlements and to test different options and measures. An application is possible for existing and planned areas
Topics analysed	Buildings: type and size of building, energy demand for heating, hot water, ventilation, electricity, options for solar energy provision (considering different heating systems) Mobility: density and type of buildings, age-groups and average commuting distances, distance to public transport infrastructure as well as to shopping and social infrastructure, parking lots per accommodation unit Renewable energy provision: district heating networks (heat density of the analysed area, large energy consumers), geothermal options
Access to the tool (public / restricted)	Public, excel-based version planned (end of 2010)
Consideration of interdependencies with a larger area	Integration in a wider area (about 300m around the analysed area), consideration of shopping supply, public social and technical infrastructure, (existing or future) large energy consumers and the potential of renewable energies in the district
Results	Primary energy demand per person and year for the field's buildings, mobility and renewable energy provision. Quantitative energy demand (per person) and classification by qualitative rating
Comparison of alternatives	Comparison is possible, but due to high data need it is rather extensive. Good options for sensitivity analyses
Further information	www.energieeffizientesiedlung.at

Source: Dallhammer et.al. forthcoming

3.3.2 Inputs and evaluation criteria

The preliminary tool is composed by four excel sheets comprising the three major fields of investigation (buildings, mobility, renewable energy) and a sheet presenting the calculated results. Calculation data will not be public in the Internet tool (references for energy demand of different building ages, heating systems, average commuting distances and modal choice at the level of districts from statistical sources, renewable energy options, etc.).

Since explicitly building related criteria is not in the focus on the work at hand, these criteria are not mentioned in the table below, which is presenting relevant criteria in the context of spatial planning.

Table 14: 'EFES' - Assessment criteria related to spatial planning

Criteria	Relevance in assessment
Buildings – type of building	Energy demand for heating
Buildings – solar orientation, considering shading by other buildings (has to be estimated)	Potential for provision of active solar energy
Mobility – general settlement structure (built up land per person)	Transport distances in commuting (public and private transport)
Mobility – distances to bank, post, general practitioner, pharmacy, primary school, kindergarten, social meeting point, sport facilities, shopping centres, cultural facilities	Transport distances and modal split
Mobility – accessibility of shopping facilities (classes of m2 shopping space)	Transport distances and modal split
Mobility – distance to public transport stop and supply (interval)	Modal split
Mobility - nr. of parking lots and distance to public transport infrastructure	Modal split
Renewable energy provision – heat density within the analysed settlement and already covered heat demand (in case of existing buildings)	Options for energy provision by a district heating network
Renewable energy provision – existence of a district heating network	Options for energy provision by a district heating network
Renewable energy provision – existence of a large energy consumer (within a distance of 5 km, within and outside of the analysed area)	Options for energy provision by a district heating network

Source: Dallhammer et.al. forthcoming

Overall there are two important branches presented for the effect analysis, one shows the energy demand of buildings and mobility, the second provides information on options for energy provision and thus coverage of this energy demand by local sources (calculatory).

Referring to the criteria of accessible shopping space for the assessment of energy demand for mobility, this criterion is stated to be problematic in villages or cities, in which the shopping facilities are located at the edge of the built up structures. Thus in such villages and cities, a development near a new 'greenfield' shopping centre would be quoted positively in this respect, although this has to be highly questioned from the viewpoint of overall energy efficient municipal development.

Additional to the data needed for the energy rating, a quite high share of data is provided from divers statistical sources especially in the field of energy demand for mobility to calculate average transport distances, modal split and elasticity in mobility (considering average regional distances to centres but also the average economic wealth of households and population structure in terms of age, job and household structure).

3.3.3 Outcome and results

Overall, the EFES rating tool is a complex calculation tool for estimating the average energy demand to be expected for different building structures and their contexts. The chosen approach – of using primary energy demand per person as calculation unit – allows for a summation of the total energy demand from buildings as well as from mobility and a comparison with the potential for local renewable energy provision.

As main results, the calculation presents the total primary energy demand per person and year for the fields of buildings, mobility and renewable energy provision. In addition a classification by a qualitative rating is provided for a general comparison with overall standards.

Figure 56: EFES - preliminary quantitative and qualitative presentation of the results and graphic implementation (topics: buildings and mobility)

Beheizung und Warmwasserbereitstellung	17,0	kWh/ Pers.,d
Haushaltsstrom	13,4	kWh/ Pers.,d
	30,4	kWh/ Pers.,d

von	bis	Klasse
0	9	A+
9	12	A
12	18	B
18	27	C
27	36	D
36	48	E
48	60	F
60	200	G

RATING Gebäude: D

Mobilität	20,0	kWh/ Pers.,d

von	bis	Klasse
0	9	A+
9	12	A
12	18	B
18	27	C
27	36	D
36	48	E
48	60	F
60	200	G

RATING Mobilität: C

Source: Dallhammer et.al. forthcoming

Figure 57: EFES - preliminary quantitative and qualitative presentation of the results and graphic implementation (topic: renewable energy)

Wärme	durch Geothermie	**100,0**	% Versorgungsgrad
	durch Biomasse (Forst)	**3,6**	% Versorgungsgrad
	durch Solarthermie	**0,5**	% Versorgungsgrad
	Wärme Gesamt	**104,1**	
Strom	Photovoltaik	**0,5**	% Versorgungsgrad
	Kraftwärmekopplung	**0,6**	
	Strom Gesamt	**1,1**	% Versorgungsgrad

von	bis	Klasse
0	5	G
5	10	F
10	20	E
20	35	D
35	50	C
50	65	B
65	80	A
80	100	A+

RATING Erneuerbare Energien	
Wärme	A+
Strom	G

Source: Dallhammer et.al. forthcoming

The outcome of the tool gives an overview on the estimated total primary energy demand and its relation to overall quality standards (by benchmarking) in terms of energy efficiency. The final assessment is divided in the three analysed main issues, there is no final total rating presented (see above).

3.3.4 Evaluation in relation to specified topics of energy aware spatial planning

The following table presents the coverage of the analysed tool by the comparison of specified relevant topics and interrelationships for energy aware spatial planning (see chapters 2.2 and 2.3) and the topics and interrelationships considered by using the analysed tool.

The tool provides information on a selection of important aspects in the spatial planning fields of location, functional mix, urban density and solar orientation, but at the same time does not consider a range of other aspects.

Topography, wind regime and street design are not considered at all.

Table 15: 'EFES' – overview on considered guiding principles by the tool

	Topography	Location, mun. shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Minimising (heat) energy losses	general wind regimes hilltops and basins wind shading avoidance of north slopes			sufficient green space use of shading	building types		airal situation	
Maximising (passive heat) energy gains	avoidance of sun shading			passive solar use options		orientation to south avoidance of sun shading		
Use of renewable energy sources	active solar use options			active solar use options	use of renewables	active solar use options		
Energy service provision *Built environm.*			heat sources and consumers		district heating densification cert. locations			
Mobility		development near PT	mixed funct. (PT demand)		options for PT			
Minimising vehicle miles travelled (VMT)	avoidance of steep slopes	short distances avoidance of dispersed settlements compact shape	mixed funct. (supply, shops)	sufficient green space	options for local supply			avoiding detours attr. design and security

.... considered .... partlyl/indirectly considered .... not considered

3.3.5 Resume

The outcome of the tool gives a good overview on the estimated total energy demand and its relation to overall quality standards in terms of energy efficiency for each of the aspects.

Nevertheless, in terms of interpretation of the results, a principle difficulty has to be mentioned due to the basis of the calculation, which is the number of persons living in a settlement. Furthermore some personal aspects as e.g. age of inhabitants, type of jobs or number of children and retired persons as well as behavioural aspects (e.g. hot water use) are integrated in the calculation. This approach i.e. leads to a better outcome of ratings for settlements which are - today - inhabited by young families (mostly with children) and especially by low-income households and thus less living space per person on average. On the one hand, the interrelation between energy demand and living space per capita is important to be considered, on the other hand, it has to be beard in mind, that inhabitants might change over time, and this rating is therefore rather an assessment, which is valid for a certain point in time – not only for the built structures itself, but also for the inhabitants and the energy efficiency of their behaviour.

Another aspect to be considered refers to the rating in terms of renewable energy options, which are calculated on the basis of regional, respectively local potential. Local availability certainly is an important factor for the supply of renewable energy in the fields of biomass and geothermal energy. Nevertheless it has to be highlighted, that the presented values solely depict theoretical coverages of energy demand (of electricity and heat). The same appears to the options for coverage of energy demand by options of building related energy provision (solar thermal installations and photovoltaics). Thus, in contrast with the ratings of buildings and mobility, which are based on (measured or estimated but) energy demand today, the outcome of the rating for renewable energy coverage is just presenting the overall possibilities to cover the energy demand by local renewable energy sources. Information on the actual coverage of energy demand by renewable energy sources is missing.

Finally, it can be stated, that the tool gives a valuable insight in differences of energy demand due to varying settlement structures and locational aspects. However, the complex calculation behind is difficult for an interpretation, an autonomous use of this tool by municipal actors and developers without support of experts seems rather unlikely.

3.4 LEED ND

Leadership in Energy and Environmental Design (LEED) was developed as a voluntary certification system for green buildings, which was constantly enhanced and refined since 1998. LEED ND is the latest extension of this rating system, *'for neighborhood planning and development based on the combined principles of smart growth, New Urbanism and green infrastructure and building'* (USGBC 2009). Thus the certification system is especially based on research related to the Charter of the Congress for the New Urbanism (e.g. Sprawl Retrofit Initiative, CNU without date) and the Urban Land Institute (e.g. Ewing et.al 2007). It shall help to implement the design and construction of buildings and settlements in a healthful, durable, affordable and environmentally sound way.

The following description is based on information from the comprehensive manual on 'LEED 2009 for Neighborhood Development Rating System' (updated July 2010) and the 'LEED 2009 for Neighborhood Development Project Checklist (XLS)', edited by the U.S. Green Building Council (USGBC 2009).

3.4.1 Scope and objectives, system boundaries

LEED ND has been developed to rate new residential, commercial and mixed-use developments in terms of their location, design and construction. Special emphasis is laid on site selection, design and construction elements, which relate buildings and infrastructure needed as well as the relation between the respective settlement and the surrounding area and the regional context.

The tool is '*designed to certify exemplary development projects that perform well in terms of smart growth, urbanism and green building*' (USGBC 2009). Such a development is considered as an alternative to urban patterns that characterise sprawl.

The topics analysed comprise: smart location and linkage, neighbourhood pattern and design, green infrastructure and buildings (and additionally innovation and design process, regional priority issues[29]). The certification is done by proofing certain basic prerequisites (12 prerequisites), which have to be fulfilled, together with additional points for compliance with the quality standards defined by the rating system.

In addition to issues of spatial planning LEED ND also considers:

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29 There are points to be achieved, which have been defined in relation to specific regional environmental issues in the USA. In maximum 4 additional points may be achieved for defined credits. Due to their restricted definition for the territory of the USA, these credits are not considered further in the analysis at hand.

- Important environmental topics as e.g. imperilled species and ecological communities, wetland and water body conservation and floodplain avoid-ance, efficient water, wastewater and solid waste management, local food production;
- Social issues as e.g. community outreach and involvement and especially mixed-income divers communities;
- Minimum building standards: certified green buildings, building energy efficiency and building water efficiency;

Though these issues are especially important in terms of obligatory prerequisites, in terms of certification points these issues cover about a third of all achievable points.

The definition of neighbourhoods comprises urban areas, which are considered as the planning unit of a town. As an appropriate range of extension to be considered as one unit, a neighbourhood of 320 acres (about 130 ha) is defined as maximum and at least two habitable buildings as minimum (not binding, but as a recommen-dation). The guiding upper limit of 320 acres or half a square mile is based on the consideration of accessibility of high-level public transport infrastructure or other, e.g. social infrastructure. It is stated an inhabitants' acceptance of about a half-mile of walk in average.

Table 16: General description of 'LEED ND' (US)

Name and author	**LEED-ND** *Leadership in Environmental and Energy Design for Neighborhood Development* **(US Green Building Council)**
Characterisation	Voluntary certification (rating system) for neighbourhood development projects, license necessary
Main issue	Energy efficiency and use of renewable energy sources for site selection (including building related energy efficiency), design and construction elements in a local and regional context, consideration of environmental and social issues Prerequisites and criteria for certification
Spatial units (size of analysed areas)	Projects up to 320 acres (ca 130 ha) are recommended to be certified, it is stated, that it is possible to certify larger areas, but certain difficulties are to be expected
Level of analysis	Precise planning at plot level, detailed information and data on the analysed area and the municipality needed
Time horizon (existing / planned areas)	Developed as certification of development projects/areas during planning phase and after construction, 3 stages (conditional approval of a LEED-ND plan, pre-certified LEED-ND plan, LEED-ND certified neigborhood development)
Topics analysed	Smart location and linkage, neighbourhood pattern and design, green infrastructure and buildings (additionally: innovation and design process, regional priority credit). Additionally to spatial issues also the topics of environment and species, wetlands and water body, water supply and waste issues as well as social issues (e.g. income) are tackled. For earning a certification it is necessary to fulfil all prerequisites and to qualify for a minimum number of 40 points.
Access to the tool (public / restricted)	Public, printed description (pdf) and Checklist Scorecard (xls) available for download, a more detailed Reference Guide has to be charged
Consideration of interdependencies with a larger area	Connectivity to surrounding neighbourhoods, access to public transport infrastructure, mixed functions, public space and recreation facilities
Results	As a result, a certification is given due to the number of achieved points (and fulfilled prerequisites). The certification ranges between 'Platinum' for 80 points and above, 'Gold' for 60-79 points, 'Silver' for 50-59 points and 'Certified' with at least 40 points.
Comparison of alternatives	A comparison is possible in terms of points achieved respectively level of certification. Nevertheless, it has to be considered, that different conditions may lead to similar levels (especially for lower certification levels). A more significant comparison is possible by comparing the 'Scorecards' of certified areas.
Further information	www.usgbc.org/leed/nd/

3.4.2 Inputs and evaluation criteria

In the following chapter, solely criteria in the context of energy aware spatial planning are considered.

The tool is structured along 3 main topics and 2 additional categories, comprising obligatory prerequisites to be fulfilled as well as additional credits for development characteristics in line with an enhanced development. All criteria together lead to a total number of points, which is decisive for the level of certification, which can be achieved.

The weighting of single credits is based on their effect on environment and human benefits by the design, construction, operation and maintenance of buildings (focusing on following impacts: GHG emissions, use of fossil fuels, toxins and carcinogens, air and water pollutants and indoor environmental conditions). They have been defined by a combination of different approaches for quantifying the impact of each of the criteria, including energy modelling, life-cycle assessment, transport analysis, etc.

In total 12 obligatory prerequisites have been defined in the certification system as shown in the following table. There are fewer prerequisites directly related to energy aware spatial planning (presented in bold letters) than prerequisites in the context of local environmental respectively geographic conditions and building related minimum standards.

Table 17: LEED ND – obligatory prerequisites

Topic	Prerequisite
Smart location and linkage	**Smart location**
	Imperilled species and ecological communities conservation
	Wetland and water body conservation
	Agricultural land conservation
	Floodplain avoidance
Neigbourhood pattern and design	**Walkable streets**
	Compact development
	Connected and open community
Green infrastructure and buildings	Certified green building
	Minimum building energy efficiency
	Minimum building water efficiency
	Construction activity pollution prevention

Source: USGBC 2010

In addition to the fulfilment of these prerequisites, it is necessary to achieve at least 40 points (credits) by compliance with additional criteria, which is defined in detail in the manual. Most of the criteria may be achieved by different (alternative or combinable) options, which are described and depicted by principal sketches (if useful).

In total, highest maximum rating is defined for the field of ‘neighborhood pattern and design’, thus this field is considered to be more important than the fields of ‘smart location and linkage’ and ‘green infrastructure and buildings’.

In terms of the composition of spatial planning criteria and other criteria per analysed field within the LEED ND certification process, the following table shows, that other (not spatial planning related) criteria are most important in terms of the topic 'Green infrastructure and buildings'.

Table 18: LEED ND – composition of spatial planning and other criteria

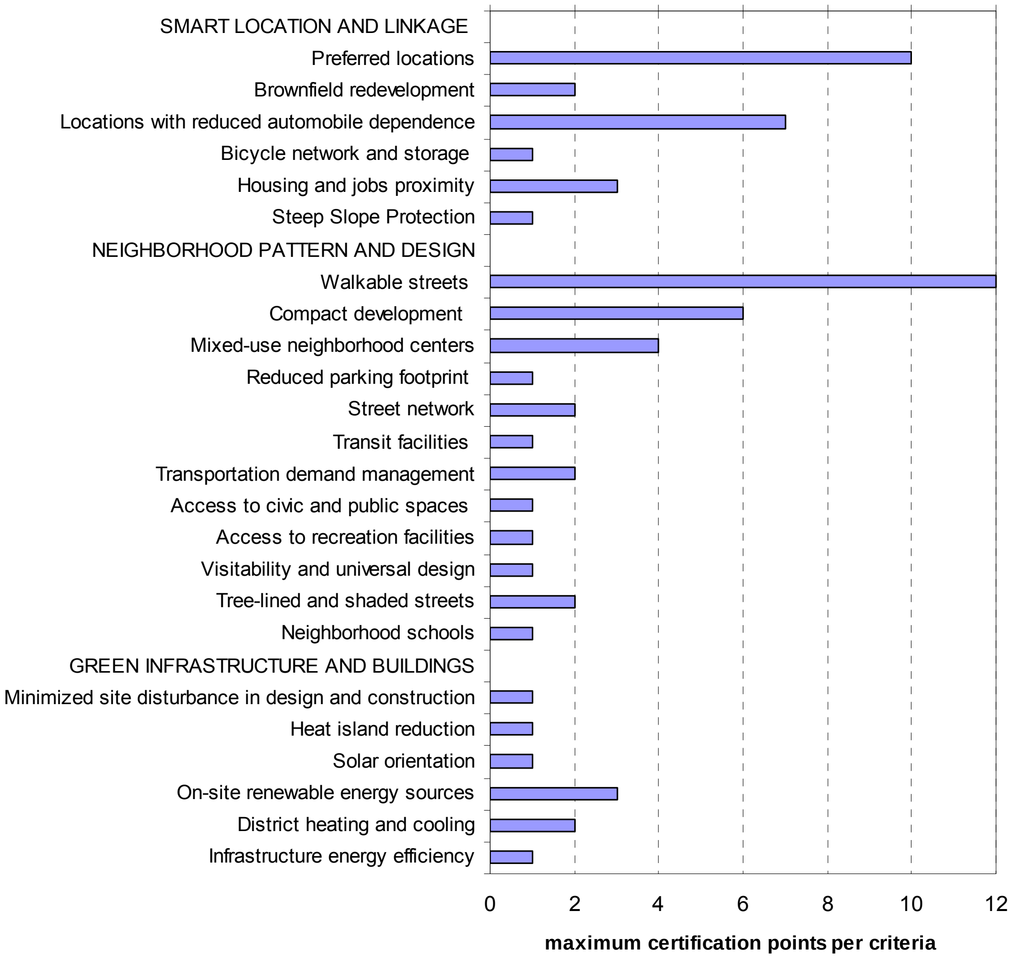
Field	Max. points for spatial planning criteria	Max. points for other criteria	Max. points in total
Smart location and linkage	24	3	27
Neigbourhood pattern and design	34	10	44
Green infrastructure and buildings	9	20	29
3 thematic fields in total	67	33	100
Innovation & design process			6
Regional priority credit			4
Total points			110

Source: USGBC 2010

The following figure (58) shows solely criteria with relevance to energy aware spatial planning (as defined in chapter 2) and their maximum achievable points per criterion. In total these criteria cover about two thirds of all achievable points.

As shown below, in terms of the importance of single criteria with relevance for energy aware spatial planning (maximum achievable points per criterion) the credits for 'walkable streets' and 'preferred locations' are weighted highest, followed by 'locations with reduced automobile dependence' and 'compact development'. Few more criteria provide with more than two points in maximum ('mixed-use neighborhood centers', 'housing and jobs proximity' and 'on-site' renewable energy sources').

Figure 58: LEED ND – criteria with relevance to energy aware spatial planning



Source: USGBC 2010

3.4.3 Outcome and results

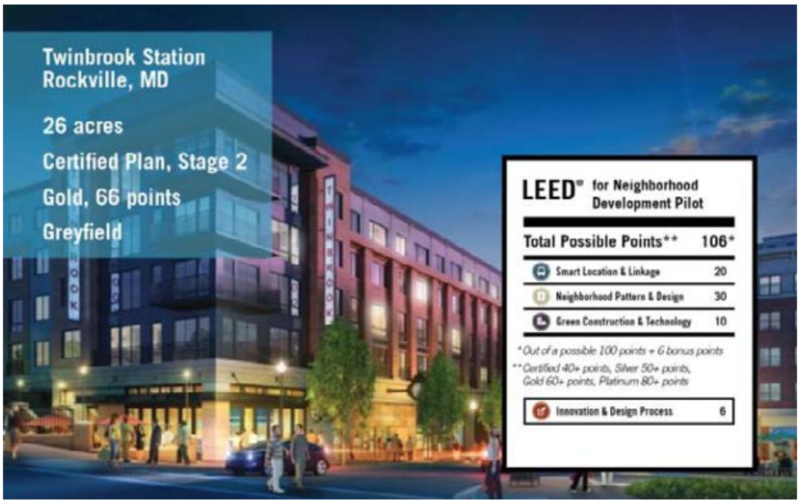
As outcome of the certification by the tool the label LEED ND may be presented, it is based on the fulfilment of prerequisites and on the achievement of total points due to the assessment of all criteria.

The final certification rating is given due to the number of points achieved (max. 110 points, with 100 base points and max. 10 bonus points for additional issues), as there are 'Platinum' certification for 80 points and above, 'Gold' for 60-79 points, 'Silver' for 50-59 points and 'Certified' with at least 40 points.

The certification label presents the number of total possible points (110 respectively 106 in case of not being of regional priority[30]). In addition the points achieved in the specified fields of attention are shown.

[30] Regional priority is defined in a list of areas for the USA. The list may be downloaded from http://www.usgbc.org

Figure 59: LEED ND – example for a certified area 'Twinbrook Station Rockville'



Source: USGBC 2009

Above an example for the certified area 'Twinbrook Station Rockville' is shown, which has been certified at stage 2 (certified plan) with 'Gold' (66 points).

3.4.4 Evaluation in relation to specified topics of energy aware spatial planning

The following table presents the coverage of the analysed tool by the comparison of specified relevant topics and interrelationships for energy aware spatial planning (see chapters 2.2 and 2.3) and the topics and interrelationships considered by using the analysed tool.

Overall, it shows a quite comprehensive assessment of interrelationships. It is clear, that even if the tool covers a wide range of issues, at the same time it strives for applicable implementation as well. A need for deep additional environmental analysis and experts integration shall be avoided, whereas information expected to be available (for US urban areas) is integrated.

As most important missing topics consideration of topography, consideration of local wind regimes and shading by buildings have to be stated. Whereas the consideration of wind regimes and shading by buildings requires detailed information from experts, the issue of topography could be easily included (at least partly) and is stated to be a major deficit regarding to the broad coverage of the tool of nearly all other important issues apart from that.

In addition a number of environmental issues are assessed and included in the final certification as well (not depicted in the figure below).

Table 19: 'LEED ND' – overview on considered guiding principles by the tool

	Topography	Location, mun. shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Minimising (heat) energy losses	general wind regimes hilltops and basins wind shading avoidance of north slopes			sufficient green space use of shading	building types		aerial situation	
Maximising (passive heat) energy gains	avoidance of sun shading			passive solar use options		orientation to south avoidance of sun shading		
Use of renewable energy sources	active solar use options			active solar use options	use of renewables	active solar use options		
Energy service provision *Built environm.*			heat sources and consumers		district heating densification cert. locations			
Mobility		development near PT	mixed funct. (PT demand)		options for PT			
Minimising vehicle miles travelled (VMT)	avoidance of steep slopes	short distances avoidance of dispersed settlements compact shape	mixed funct. (supply, shops)	sufficient green space	options for local supply			avoiding detours attr. design and security

.... considered .... partlyl/indirectly considered .... not considered

3.4.5 Resume

'LEED for neighborhood development' clearly is a certification system for top developments to be applicated from licensed experts.

Due to its very detailed definition of prerequisites and credits (as described in examples and different options in the manual for application) the results for different areas are expected to be comparable in principle. Certification for different development stages allows for an enhancement of urban development during the development process.

In total, the assessment tool covers a high number of defined interrelations between spatial planning and energy issues. The lack of criteria evaluating consideration of topography issues is seen as an important missing factor for the evaluation.

Nevertheless, there are two major deficits of this system to be mentioned. These disadvantages are stated to be common for most of the certification systems providing with a quality label for good or best urban development, which can be used for marketing purposes as well:

- Due to the additional costs for the work of licensed experts and the certification itself, the tool will be used mainly for top projects and lead developments.
- In addition, it is even not useful for low quality urban areas in order to lower energy demand and environmental damage since such developments are not able to fulfil the necessary prerequisites and credits for certification at all.

Overall, LEED ND can be seen as a valuable certification system for sustainable urban development and awareness rising. But it has to be taken into consideration, that selection of certified areas is rather at the top end of urban development options.

3.5 BREEAM Communities

BREEAM (BRE Environmental Assessment Method) is a widely used assessment method for buildings, which has been developed in UK. BREEAM Communities shall improve the sustainability of the built environment by supporting development projects in the planning stage (tailored to the situation in English regions). The objective of sustainable urban development especially focuses on *'communities in which people can work, shop, learn and play near their homes, and not have to drive* *miles from residential areas to distant business districts, shopping centres, schools and other facilities*’ (BRE Global Ltd 2009).

The tool has been developed lately; only few pilot studies in England have been finished so far. The description of the tool is based on information from the comprehensive Technical Guidance Manual for BREEAM Communities edited by BRE Global Ltd 2009.

3.5.1 Scope and objectives, system boundaries

The tool shall analyse and rate the overall sustainability of projects by a holistic label comprising environmental, social and economic aspects. Hence – similar to LEED ND - it is including spatial planning in the assessment, but goes far beyond in the rating procedure.

In principle the assessment may be carried out for domestic, mixed use and non-domestic types of projects and for new developments as well as for regeneration projects. Referring to the size of analysed developments, there is a typology given defining small developments (up to 10 units), medium developments (11 to 500 units) and large developments (above 500 units). There is no size of surface area given as indication.

By using BREEAM Communities eight categories of sustainable urban development are assessed along the following topics:

- Climate and energy: flood management, energy and water efficiency, renewable energy, infrastructure, passive design principles
- Resources: land use and remediation, material selection, waste management, construction management, modern methods of construction
- Transport: walkable neighbourhoods, cycle networks, provision of public transport, green travel plans, construction transport
- Ecology: maintaining/ enhancing habitat, green corridors, ground pollution, contaminated land, landscaping schemes
- Business: inward investment, local employment, knowledge sharing, sustainable charters
- Community: social impact assessment, community engagement, sustainable lifestyles, facilities management, mixed use, affordable housing
- Place shaping: site selection, defensible space, active frontages, green space, secured by design, housing density
- Buildings: UK/English certifications - BREEAM buildings, code for sustainable homes, EcoHomes

Each of the eight categories is outlined by a number of detailed issues (more detailed than topics above), which are defined by a performance target and assessment criteria to be achieved as well as by additional available credits. Only if the performance target is confirmed, credits can be awarded.
These credits are weighted by regional importance, which has been predefined for all nine English regions. For projects in other regions it is necessary to contact BRE Global Ltd to create a so-called 'Bespoke BREEAM Communities Standard'.

Table 20: General description of 'BREEAM Communities' (UK)

Name and author	**BREEAM Communities** – *BRE Environmental Assessment Method for Communities* **(BRE Global Ltd, UK)**
Characterisation	Voluntary certification standard (rating system) for development projects, license necessary
Main issue	Mitigation of overall impacts of development projects within the built environment by planning sustainable communities, provision of an environmental, social and economic sustainability label for development projects Assessment tool tailored to England (legislation and planning policy requirements), nevertheless there is an offer for assessment of international projects as well Rating benchmarks, regional weightings, mandatory requirements and credits for innovation
Spatial units (size of analysed areas)	No surface area is given, size of projects is defined by a typology depending on the number of units (up to 10, 11-500, above 500 units)
Level of analysis	Precise planning at plot level, detailed information and data on the analysed area and the municipality needed Consultation of professional expertise and calculations, commitments of developers and local stakeholders and official evidences from the local community and other planning authorities are asked for a number of topics.
Time horizon (existing / planned areas)	Developed as certification of development projects/areas in the stage of planning for new and regeneration projects - Interim BREEAM Communities Certificate (based on the outline planning stage) and Final BREEAM Communities Certificate (based on the detailed planning stage)
Topics analysed	Coverage of eight categories of sustainability: climate and energy, resources, transport, ecology, business, community, place shaping and buildings
Access to the tool (public / restricted)	Public, printed manual (pdf) available for download, tables and checklists are not public
Consideration of interdependencies with a larger area	Mainly in terms of connectivity to neighbourhood areas, and consideration of context in design issues At a larger scale an evidence of the need for the development is obligatory
Results	As a result, a certification is given due to the achieved score. The certification ranges between 'Outstanding' for above 85% and additional requirements, 'Excellent' for a score of 70-85%, 'Very Good' for a score of 55-70%, 'Good' for a score of 40-55% and 'Pass' for a score of at least 25%.
Comparison of alternatives	Comparison is possible by analysing alternatives by the tool
Further information	www.breeam.org

In contrast to the other analysed tools, a considerable number of topics have to be confirmed by various stakeholders and from authorities mainly based on legal regulations (in England), additionally the consultation of professional expertise is asked for some aspects.

3.5.2 Inputs and evaluation criteria

In total, the tool is based on 51 criteria, which are classified along eight categories. Most of the criteria are to be applied for all analysed settlement projects, only few are restricted to e.g. medium and/or large projects and projects of mixed use. In general, for each criteria achieved between 1 to 3 credits may be achieve in dependence on quality factors. About the half of the criteria is mandatory, the remaining criteria support the project by counting for additional credits.

Each of the criteria is weighted by regionally defined factors (for UK regions).

Referring to spatial planning more than 50% of criteria from 4 categories are covering spatial aspects at least partly, of which transport and place shaping are more important within the assessment (see table below). The criteria and their quality (1 to 3 credits) are described in detail but without depiction in maps or sketches. For further information, a number of studies and legal regulations are referenced.

Table 21: BREEAM Communities – criteria referring to energy aware spatial planning

Category	Criteria
Climate and energy (5 criteria)	Mandatory: Energy efficiency (building envelop, orientation, etc.), onsite renewable(s), future renewables (solar use), services of technical infrastructure *Non-mandatory: Heat islands*
Transport (11 criteria)	Mandatory: Public transport facilities (real time information, shelters, etc.), local amenities (neighbourhood shopping, local supply etc.), facilities for cycling, local parking organisation, transport assessment *Non-mandatory: Home zones, car clubs (car sharing etc.), flexible parking zones (other uses), cycling network, location/capacity of public transport, availability/frequency of public transport*
Business (4 criteria)	*Non-mandatory: Business priority sectors, local employment, new business, investment (mixed functions)*
Place shaping (8 criteria)	Mandatory: Sequential approach (evidence of the need for development, use of brownfields and contaminated land), design and access (context, spatial relationship, connectivity to neighbourhoods, urban design) *Non-mandatory: Green areas, secure by design, active frontages, defensible spaces (distinction of private and public open spaces), land reuse, building reuse*

Source: BRE Global Ltd 2009

As only tool, BREEAM Communities includes a holistic view on municipal development by considering needs for new developments in principal as well as by rewarding the reuse of land and buildings and thus laying emphasis on inner development of municipalities.

In terms of energy aware spatial planning, especially the definition of central transport criteria, namely location and capacity as well as availability and frequency of public transport, only as non-mandatory – and thus voluntary – measure is stated to be questionable. Spatially relevant criteria in the category of 'business' are all stated non-mandatory.

3.5.3 Outcome and results

As outcome of the certification the label of BREEAM Communities – BRE global mark can be achieved, which is based on the fulfilment of mandatory criteria together with a minimum percentage of criteria achieved in total.

Figure 60: BRE global mark

Source: BRE Global Ltd 2009

The final rating is characterised by the quota of (weighted) credits. For the analysed project (or area) a certificate is provided with a quality rating as there are 'Outstanding' (*****) for above 85% and additional requirements, 'Excellent' (****) for a score of 70-85%, 'Very Good' (***) for a score of 55-70%, 'Good' (**) for a score of 40-55% and 'Pass' (*) for a score of at least 25%.

3.5.4 Evaluation in relation to specified topics of energy aware spatial planning

The following table presents the coverage of the analysed tool by the comparison of specified relevant topics and interrelationships for energy aware spatial planning (see chapters 2.2 and 2.3) and the topics and interrelationships considered by using the analysed tool.

As shown, BREEAM Communities covers a relatively high number of identified issues and topics. Nevertheless, it has to be stated, that it mainly lacks aspects of common energy services provision and the consideration of density in general.

Table 22: 'BREEAM Communities' – overview on considered guiding principles by the tool

	Topography	Location, mun. shape	Functional mix of uses	Green spaces	Urban density	Solar orientation	Wind regime	Connectivity, street design
Minimising (heat) energy losses	general wind regimes hilltops and basins wind shading avoidance of north slopes			sufficient green space use of shading	building types		airal situation	
Maximising (passive heat) energy gains	avoidance of sun shading			passive solar use options		orientation to south avoidance of sun shading		
Use of renewable energy sources	active solar use options			active solar use options	use of renewables	active solar use options		
Energy service provision *Built environment*			heat sources and consumers		district heating densification cert. locations			
Mobility		development near PT	mixed funct. (PT demand)		options for PT			
Minimising vehicle miles travelled (VMT)	avoidance of steep slopes	short distances avoidance of dispersed settlements compact shape	mixed funct. (supply, shops)	sufficient green space	options for local supply			avoiding detours attr. design and security

.... considered .... partlyl/indirectly considered .... not considered

3.5.5 Resume

BREEAM Communities has to be applicated from licensed experts with need for other experts and official documents and commitments. Hence the high number of thematic expertise and written commitments, which is needed, is expected to prolong the certification process considerably. Similar to LEED ND, it is mainly a certification system for top developments.

Overall, the tool covers a comparingly high number of defined interrelations between spatial planning and energy issues. In addition to the missing credit for district heating networks, the lack of factors valuating density and building types is especially seen as deficiency of the tool.

Issues and credits are described in detail, but the approach tailored to English regions, may be difficult to be transferred to other regions. Nevertheless, for alternative locations and different projects the results for are expected to be comparable in principle.

An interesting emphasis is laid on the consideration of needs for new developments as well as on the reuse of land and buildings. Although this aspect of holistic sustainable municipal development can be stated to be of high importance from the viewpoint of holistic municipal development, this element of sustainable urban planning and development of inner areas of built up structures is not included explicitly in the other tools.

The general disadvantages, which are common for many certification systems to be awarded by licensed processes, are valid for BREEAM Communities as well[31]. Nevertheless, overall BREEAM Communities is a valuable certification system for comprehensive sustainable urban development and awareness rising.

3.6 Comparison of analysed tools

The analysis of existing tools shows a range of varying approaches for assessment with different objectives and target groups as well as different issues, which are considered by the assessment.

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31 As stated for the certification of LEED ND:

- Due to the additional costs for the work of licensed experts and the certification itself, the tool will be used mainly for top projects and lead developments.
- In addition, it is also not useful for low quality urban areas in order to lower energy demand and environmental damage since such developments are not able to fulfil the necessary prerequisites and credits for certification at all.

Overall, the tools 'Energieausweis für Siedlungen' and EFES comprise rating systems including quantitative estimations (with 'Energieausweis für Siedlungen' including also qualitative ratings), whereas LEED ND and BREEAM Communities are certification systems with qualitative assessment (points/credits) and defined prerequisites or mandatory credits for certification.

The following table shows most important characteristics of the analysed tools, comprising objectives, issues, target groups as well as application characteristics and outcomes.

Table 23: Overall comparison of tools

	Energieausweis für Siedlungen	EFES	LEED ND	BREEAM Communities
Overall objective	Rating of energy efficiency together with budgetary effects for the municipality	Estimation and rating of energy demand of settlements	Certification of energy efficiency by assessing principles of planning	Certification of energy efficiency by assessing principles of planning
Issues considered	Spatial planning, infrastructure and municipal finance issues	Buildings, spatial planning and renewable energy	Buildings, spatial planning, environmental/ ecological and social issues	Buildings, spatial planning, environmental/ ecological and social issues
Target group	Municipal actors	Research, municipal actors	Investors, municipal actors	Investors, municipal actors
Application	Simple in general, detailed data on the project needed	Detailed data on energy demand, building quality and heating systems needed	Licensed application only, detailed data on the project and additional legal regulations needed	Licensed application only, detailed data on the project and additional expertises, commitments and legal regulations needed
Type of outcomes	Quantitative result and graphic benchmarking	Quantitative result and graphic benchmarking	Qualitative result, achieved points and certification level	Qualitative result, achieved percentage and certification level
Range of outcomes	Levels from A+ (very good) to G (bad)	Levels from A+ (very good) to G (bad)	Levels only from 'Certified' (good) up to 'Gold' (very good)	Levels only from 'Pass' up to 'Outstanding'

Referring to the topics considered, the tools also show a major differentiation between quantification-tools and those tools working with qualitative inputs. The latter show a far higher consideration of considered topics and interrelations than the former. Clearly, this is partly also the result of the integration of aspects, which are difficult to be quantified, and thus cannot be integrated in quantification-tools easily.

Table 24: Comparison of tools by coverage of spatial planning topics

Topics considered	Energieausweis für Siedlungen	EFES	LEED ND	BREEAM Communities
Topography	+	-	o	o
Location, mun. shape	++	++	++	++
Functional mix of uses	+	++	+	+
Green spaces	o	-	++	++
Urban density	o	+	++	o
Solar orientation	+	++	++	++
Wind regime	-	-	-	++
Connectivity	+	-	++	+
Coverage of 31 inter-relations identified	10	12	21	17

Note:
++ ... totally/widely considered, + ... partly considered, o ... considered little, - ... not considered at all

The tools of 'Energieausweis für Siedlungen' and 'EFES' cover only about a third of defined interrelations between spatial planning and energy issues. Whereas 'Energieausweis für Siedlungen' includes aspects of more topics, the EFES-tool seems to focus on deep consideration of fewer topics.

LEED ND is covering about two thirds of all interrelations defined. As main deficiency the lack of topography consideration has to be stated. This topic – which is in principle simply to be integrated – is missing widely in the certification process by the LEED neighbourhood tool.

Similar to the US tool, also BREEAM Communities covers a wide range of interrelations. As a major lack the missing consideration of common energy services provision and the consideration of density in general is identified. In addition, BREEAM Communities requires a lot of expertise and official paperwork (tailored to English regions) for achieving credits.

Overall, the comparison highlights a principal distinction between tools for quantification of effects and certification tools. Furthermore, in detail considerable differences are presented in terms of analysed topics and issues relating to spatial planning and its effects on energy issues between all four tools.

In addition, especially the certification tools LEED ND and BREEAM Communities cover other topics and aspects as i.e. biodiversity, habitats, resources, water management, social and governance issues etc.

Due to their objectives (beyond energy aware spatial planning), the analysed assessment tools vary notedly. Thus the outcomes from those tools for a specific case study are expected to differentiate considerably, a direct comparison of the tools is considered not feasible.

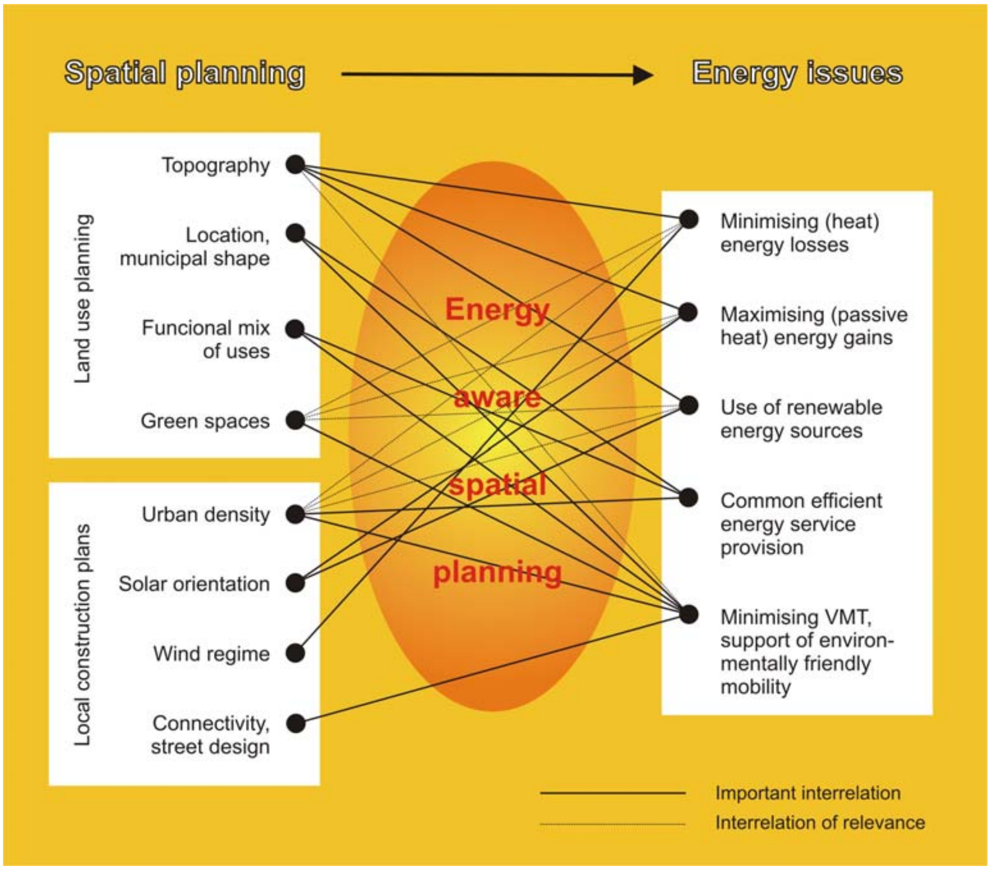
4 Summary and Synopsis

4.1 Measures of spatial planning affecting energy demand

Spatial planning has a substantial impact on the future energy demand of cities and villages by defining future land use options in general and local construction in detail. The crucial decisions on which land is used and how it is used lead to specific functional mixes and settlement structures, which again affect energy efficiency and/or options for the use of renewable energy.

From the literature review, it can be concluded, that there is not one single topic or measure of spatial planning, which is more important in terms of reduction of the overall energy demand of a settlement and further of an entire municipality. Instead it is a package of various measures, which can contribute to energy efficiency and mitigation if integrated implementation takes place. Even though the effect of single measures can vary widely it is possible to define general guidelines leading to higher energy efficiency in total.

Figure 61: Energy aware spatial planning - from spatial planning to energy issues



Thus a high contribution to a reduction of the energy demand and according CO_2 (and other GHG) emissions can be achieved if energy issues are taken into consideration seriously. Real savings are dependent on the specific situation and characteristics. For new settlements very roughly – solely by following the principles of energy aware spatial planning (without building related measures) – between less favourable and favourable locations and buildings characteristics at least about half of the energy demand for heating could be saved and private transport-related CO_2-emissions could be reduced for about 40-60%. In addition a saving up to -80% of CO_2-emissions is possible by introduction of biomass-based district heating networks.

Land use planning together with local construction plans

Land use planning forms the background for energy aware planning, which is refined and supplemented by local construction plans as an instrument of 'fine tuning' at specific locations. Referring to land use planning it is important to focus on the municipality as an entity. Principal decisions on the location of measures should be compared against optional alternatives. Local construction plans in contrast are usually focussing on a specific area, surrounding conditions are less important in this (later) phase of planning.

Both scales of spatial planning – land use planning and local construction plans – can have a considerable impact on the energy demand in the sphere of the built environment as well as on the sphere of mobility. Referring to the influence on the two considered spheres of living land use planning is setting important framework conditions for the built environment, while it is even more important for mobility issues. In contrast, besides urban density, the planning scale of local construction plans is less important for the sphere of mobility, but it can contribute considerably in terms of the energy demand caused by characteristics of the built environment.

Especially for the sphere of mobility synergies of measures with energy efficient effects are very important. Synergies, achieved by an integrated approach of planning, can lead to considerable success (best results can be achieved by common concepts for location and municipal shape, functional mix and urban density).

Whereas it is more difficult to analyse the effects of changes on single plots spread over the entire municipality (in a filling up process within the already built up land), the changes in terms of energy efficiency and options for renewable energy due to the construction of new areas can be estimated more accurately. Dependent on

both the size of the development area and of the municipality the effects can be considerably for the development area itself as well as for the entire municipality.
Nevertheless, also the way that single plots are used is affecting if energy efficiency and the use of renewable energy for this specific unit as well as in interrelation with the surrounding area (e.g. densification) is supported or rather counteracted.
For spatial planning actors deciding on spatial regulations it is of utmost importance to be aware of such interdependencies and – at least – of the most important factors influencing the energy demand of a municipality and options for energy efficiency and the use of renewable energy for its inhabitants.

Urban density as a key question

Urban density is a key question both, in terms of importance for a number of aspects of energy demand by affecting the sphere of built environment as well as the sphere of mobility as well as for balancing trade-offs. Decisions on urban density should be based on careful analysis of interdependencies and overall objectives for future development.
The grade of urban density itself influences a number of interrelations directly referring to energy demand (especially in the context of common energy services referring to district heating systems as well as to public transport supply) but also to other issues as e.g. the feasibility of shops and social facilities within a neighbourhood. In this respect not only the density within a specific settlement, but also the situation in neighbouring areas and critical masses of population (and jobs) in a certain area are of importance. In addition to favourable options due to higher levels of density, its interference with other energy issues (solar use, use of renewables in general, heat island effect) has to be taken into account.
Overall, although stated to be an important instrument for the development of energy efficient settlement structures, setting density thresholds is a highly sensitive topic (also in terms of acceptance of certain density levels in varying urban and rural structures), which has to be balanced carefully case by case, depending on the framework and locational conditions. The presented approach for defining an ‘appropriate density range’ for a specific area by integrated consideration of energy related aspects as well as other important factors might support deliberate decisions for more energy efficient urban development.

Counteracting effects to be considered

From the perspective of energy aware planning, integrative conceptualisation of local construction plans is more difficult due to a number of trade offs between single aspects. In case of single locations it is valuable to follow the general principles for planning as defined above. For urban development projects of a certain size, supporting calculation models should be used in order to achieve an optimisation by balancing synergies and trade-offs.

Counteracting effects have to be taken into consideration especially for following interrelations.

In a certain constellation consideration of topography might interfere with the objective of minimising vehicle miles travelled (VMT). In case of available land near the centre but located at a North slope, the objective to strive for short distances and a compact municipal shape interferes with avoidance of unfavourable orientation. In addition to the total estimated energy demand also quality of living has to be taken into consideration in such cases. The decision on building up such areas (for housing or other purposes) has to be taken carefully.

In general, urban density supports energy efficient development by enhancing public transport and other communal services. On the other hand, urban density (at a certain level) interferes with the possibility of maximising energy gains as well as the use of renewable energy sources. In addition consideration of wind regimes (for reducing energy demand for heating) in context with urban density may counteract with cooling effects in the summer season (in order to lessen heat island effects).

The interrelation of trade-offs has to be analysed case by case, implementation measures should be decided due to the results of balancing analysis and defined priorities.

4.2 Relevance, opportunities and restrictions of assessment tools

General relevance of tools

The hereby undergone analysis of existing tools for assessment shows, that the interrelation between spatial planning and energy issues is integrated in the tools widely. Hence, the tools in principle achieve the overall objective of depicting differences of settlement projects due to characteristics of the built environment and locational questions. Considered assessment criteria are similar, even though there are considerable differences in detail. As presented, the tools follow varying objectives for the calculation respectively for the rating of development projects and built up areas. Findings of tools vary considerably due to different priorities, criteria and weightings and are cannot be compared directly. Thus information about the background of the assessment is necessary for a detailed interpretation of such findings.

The effects of synergies or trade-offs cannot be highlighted by tools working with relatively simple inputs, due to the complex interrelationship of measures and impacts. This would only be possible by developing a model for every specific municipality, ending up with a major effort for research and calculation.

Consideration of municipal development

Despite the fact that the context of municipal development trends is of high importance for the overall sustainability of a new settlement area, this issue is only analysed in one tool (BREEAM Communities). In this tool, the general necessity of a new development has to be proven. For municipalities with shrinking population, it will be more difficult to verify i.e. the need for additional housing if the centre is becoming increasingly depopulated at the same time.

In addition to the consideration of population development, also the integration of the analysed projects in the municipality is a rather neglected assessment task. All analysed instruments focus on the level of settlements, starting the assessment rather after land use planning has been done. Effects on densification of larger areas (effects on neighbouring areas), alternative locations and distribution of the functional mix within the municipality as well as effects on the overall shape of the municipality are not considered by the tools. An assessment of more appropriate locations can only be done by the comparison with findings for alternative projects. This clearly tributes to the need for much higher efforts for information about the municipality in case of higher integration in the municipal situation.

Hence, even though locational factors are analysed (e.g. short distances, accessibility of shops, public infrastructure, etc.) and alternatives may be compared by the tools, the lack of principally questioning the location and the analysed development measure in the context of the municipal characteristics and development trends has to be seen as a major constraint of those tools for being used as tool for advising municipal actors and for estimating the impact of certain measures on the overall sustainability of municipal development.

Opportunities of the use of assessment and certification tools

Even though there have to be stated important shortcomings of the tools in terms of consideration of overall municipal characteristics and future development trends, they are expected to be useful for awareness raising and as a basis for further discussion at a local scale.

Whereas the analysed certification tools (LEED ND and BREEAM Communities), which are not yet common in Austria, are mainly considered effective for marketing issues and thus may raise awareness on quality issues of settlements, the 'Energieausweis für Siedlungen' can be used as an instrument for awareness raising of municipal actors. In this respect, the combination of costs and energy efficiency might be even of higher use than a purely energetic assessment of settlement structures, especially for small municipalities. Also the tool of EFES is expected to be able to contribute to awareness raising, but due to its higher complexity, this tool can serve mainly for discussion with experts of municipal development (also municipal actors) and within the research community.

4.3 Energy aware spatial planning and sustainable municipal development

Planning in the framework of municipal characteristics and development trends

Overall it has to be stated, that in reality the complex mix of varying contexts makes it difficult to estimate the effect of specific measures or even compare the outcome of such measures after implementation. Effects on energy demand by spatial planning under different conditions can only be estimated and simulated, a 'reality check' by transformation usually needs decades, a comparison of two options under the same conditions is not possible due to differing framework conditions in every location.

Thus decisions on spatial developments should be based on general interrelationships considering the guidelines defined above, but at the same time critically assessed against the existing framework as well as in terms of their relevance and validity and the options to trigger a development towards higher energy efficiency of our built structures.

Energy aware spatial planning in the context of sustainability

Naturally, there are a large number of additional issues to be considered in the context of communal organisation and development besides energy aware spatial planning for municipalities. In fact, it is not feasible to define a general – neither higher nor lower – weight of the issue of energy aware spatial planning against other questions in the context of sustainable municipal development. In addition to energy issues also other ecologic as well as economic and social issues have to be taken into account. In case of conflicting targets and/or limited budgets, objectives and priorities have to be analysed and balanced to each other.

In addition, decisions certainly have to be based on open options and room for manoeuvre for municipal actors. Referring i.e. to land use planning, it is usually not a question of choosing new land for housing without restrictions, but (due to private ownership) rather a decision between few possible (available) locations (if at all). Nevertheless it has to be stated, that the room for manoeuvre (according to current legislation in Austria) often is larger than is made use of by mayors. There is still a large potential for enhancing a more sustainable development in communities (mainly depending knowledge and political courage).

Possibilities to make use of this potential can be clearly seen in considering and widely following the guiding principles of energy aware spatial planning – as defined in this master thesis – and in using existing assessment tools especially for awareness raising for future decisions in the range of municipal spatial development.

Final Conclusion

How built up structures are configured and organised is one of the key questions for the future energy demand of earths population. Spatial planning decisions have a major impact on the development of new settlements (in terms of location, densities, orientation of buildings, etc.) as well as on the transformation of already existing built structures and thus affects energy demand for space heating and transport issues. Issues as i.e. options for the use of solar energy on buildings, opportunities for the supply with public transport or options for district heating networks show a high dependency on certain characteristics of built up structures. Hence, spatial planning, used as an anticipatory and impact oriented instrument, is able to contribute to setting the course towards a more energy efficient urban structure of our built environment and life within those structures.

In addition, a more resource-oriented way of living is also especially important in the context of communal budgets as well as for private persons due to increasing costs for fossil fuels. Higher independency from fossil fuels will be an important question for the future also directly linked to questions of distributive equity and economic wealth in general as well as sufficient income or increasing (fuel) poverty for a considerable share of population.

The forthwith alignment of municipal decisions with urban, energy efficient development objectives is necessary in order to achieve a perceptible contribution to the transformation of the built environment. Due to the high reluctance of existing built structures, this is only possible in mid to long term. Therefore decisions have to be taken on the basis of sound knowledge on the multifaceted and complex interdependencies between spatial structures and related energy issues for both, the enhancement of existing structures as well as new development areas.

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